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PIONEERS OF ELECTRICITY

OR

SHORT LIVES OF THE GREAT ELECTRICIANS

BY

J. MUNRO

AUTHOR OF 'ELECTRICITY AND ITS USES,' ETC.; JOINT-AUTHOR OF 'MUNRO AND JAMIESON'S POCKET-BOOK OF ELECTRICAL RULES AND TABLES'

LONDON
THE RELIGIOUS TRACT SOCIETY
56, PATERNOSTER ROW; 65, ST. PAUL'S CHURCHYARD
AND 164, PICCADILLY
1890

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PREFACE.

THE lives imperfectly depicted in the following pages were those of men who occupy the front rank in electrical discovery. They are eleven in number, and range from Thales, the Milesian, who flourished 600 years before the Christian era, to Clerk Maxwell, who died in 1879. We have begun with Thales because he was acquainted with the first isolated fact about electricity, namely, that a piece of rubbed amber attracted straws, and endeavoured to account for it by the existence of a 'dæmon' in the stone.

The modern science was founded by Gilbert, who discovered the magnetism of the earth. It was vastly extended by Franklin, who disclosed the electricity of the atmosphere. Volta furnished the world with a new source of the electric fire. Ohm and Coulomb established the laws of electrical action. Others opened up new branches of the science, and showed its connection with other physical sciences. Such were Oersted, Ampère, and Faraday, three names that shine amidst their fellows like the brilliant stars
hich gem the baldric of Orion. Finally Maxwell
s to have identified the 'dæmon' of Thales with
miniferous ether which pervades all bodies, and
omena of electricity with those of

light and heat, and, it may be, with other forms of energy.

In referring to the leading discoveries of these illustrious men, an attempt has been made to describe them in a simple manner, so as to be understood by the untechnical reader.

It is worthy of note that seven of these great investigators, that is, the majority, were disposed to cultivate the art of poetry. All of them pursued their experiments with the simple object of arriving at the truth, not on purpose to enrich themselves, but in the certain hope of assisting their fellow-men.

It is also believed by many that the study of natural science tends to produce an active antagonism, or, at least, a cold indifference towards Christianity. But the reader will find that these master-minds in one of the greatest and most profound lines of research have seen no reason to give up their faith. Faraday and Maxwell, who lived in our own day, were as remarkable for their Christian piety as for a rational insight into the nature of things surpassing that of their contemporaries.

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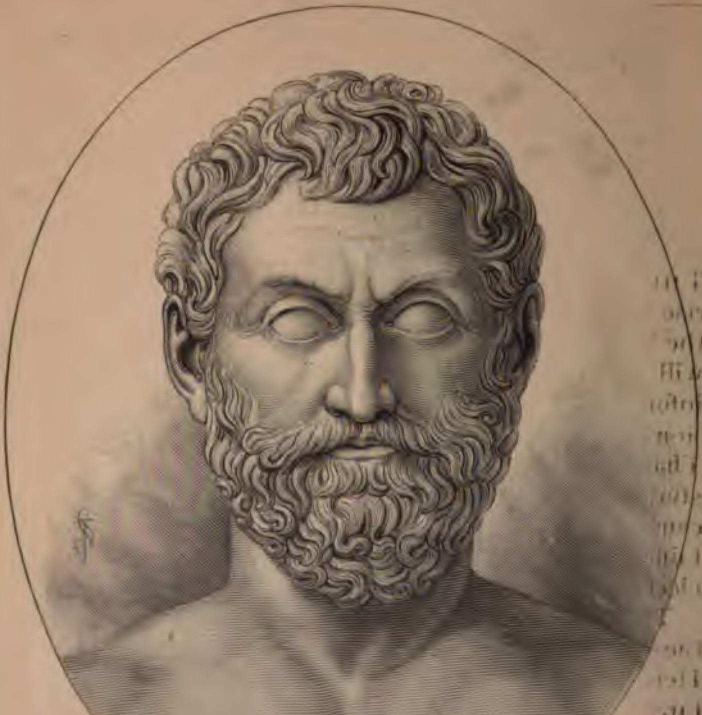

THALES.

THE [illegible] 346 WEST [illegible] NEW YORK CITY

THALES.

THE science of electricity and magnetism took its rise from the attractive property in rubbed amber and the lodestone. How and when this was first observed will probably remain a mystery; but classic authors inform us that Thales of Miletus attributed the attraction to a 'soul' or spirit dwelling in the stones. As Thales was the first on record who appears to have studied the phenomena and speculated upon their cause, we have come to regard him as the fountain-head of the science, and the patriarch of all electricians.

Thales flourished before the dawn of history, and the little we know of him is mainly traditional. Herodotus, who lived a century later, Aristotle, Plutarch, and others, mention the philosopher in their works, for his fame extended through all Hellas, and even to the barbarians; but the most particular account of him preserved to us is the short 'Life' compiled by Diogenes Laërtius.

Thales was born in the city of Miletus, in or about the year 640 B.C.[1] Miletus was the capital of Ionia, a colony of the Athenians, on the western coast of Asia Minor. The settlements of the Greeks were often mere towns planted on the isles and capes of the Mediterranean; but Ionia was a strip of territory

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[1] The first year of the 35th Olympiad, according to Diogenes Laërtius. The Olympiads were periods of four years reckoned from the victory of Koræbes in the Olympian Games.

ninety miles long, from the island of Chios on the north to the Iasian Gulf on the south, and from twenty to thirty miles broad. Above it were the Æolians, and below it the Dorians, while the highlands of the interior were inhabited by the native Carians, Phrygians, and Lydians. Ionia contained twelve beautiful cities, and ancient writers tell us that it boasted as many marvels as Greece herself. The climate, according to Herodotus,[1] was the most delightful in the whole world. The prolific soil was watered by refreshing streams, the valleys teemed with flowers and fruit, the mountains were furnished with groves of timber and precipices of marble. The uneven coast afforded excellent harbours, as well as captivating glimpses of the blue Ægean and the rocky islands of the Archipelago. Nor were spiritual associations wanting to a land peopled by the Hellenes. Divine myths clustered around well and grotto; the fanes of heroes arose by the wayside, and magnificent temples adorned the cities.

Miletus in the days of Thales was a flourishing metropolis. It was built on a promontory of the Latmian Gulf, beside the mouth of the Meander. Its territory extended from the peninsula of Posidion to the fertile holms of that famous river. The city was walled, as usual in those times, and possessed four ports, one of which was capable of sheltering a fleet of galleys. For the Milesians were a maritime people; their commerce extended throughout the Mediterranean as far as the Pillars of Hercules, and they had planted nearly a hundred colonies on the shores of the Euxine and Propontis, of which Abydos and Sinope are still extant. Their staple export was wool from the highlands of Phrygia; but the bazaars of the city were filled with hides from the Black Sea,

[1] *Herodotus, i.* 142.

carpets from Sardis, frankincense from Arabia, ivory and gold from Egypt, and purple silks from Tyre and Sidon.

The walls were surrounded by olive gardens, vineyards, and cornfields. A group of rocks, called Ladé, marked the middle of the gulf and protected the harbour. On the woody slopes of Mycalé opposite stood the white city of Priene, the home of Bias, a contemporary of Thales. Eastward the eye rested on the forests of Mount Griou, the distant peaks of Latmos, and the silver links of the Meander, winding among groves of tamarisk and myrtle down from the blue hills of Phrygia. Westward, beyond Cape Mycalé, lay Samos, the birthplace of Pythagoras, and other legendary islands of the Ægean, Cos, Patmos and Icaria.

The chief glory of the district, however, was the temple of Apollo Didymi, or Branchidæ, seated on the brow of the Posidion, overlooking the sea, and commanding a noble prospect. The legend went that Apollo, finding the boy Branchus herding his goats among the heathy vales of Didymæus, and being struck with his beauty, bestowed upon him the gift of prophecy. The priestess, like that of Delphi, was inspired by the fumes of a mephitic spring, and the oracle was famous throughout the whole East. Crœsus, King of Lydia, consulted it before making war upon Cyrus; and the Pharaoh Neco of Scripture, on defeating Josiah, King of Judah, at Megiddo, dedicated to the god the corslet he had worn during the battle.[1] The temple was built in the Ionic style, and connected to the port of Panormus, two miles to the south, by a 'sacred way' or avenue, bordered for part of its length by colossal figures in stone, after the manner of the Egyptians.[1]

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[1] Herodotus, i. 46, 92; ii. 159. Crœsus presented a golden shield, as at Delphi. Both events occurred about the time of Thales, the former, 548-6 B.C., the latter, 608 B.C.

The inhabitants of Miletus were doubtless of various origin, for it was originally a settlement of the Carians,[2] and when the Athenian colonists under Neleus attacked it, about the years 1000 to 1100 B.C., they put the men to the sword and took the women as their wives. Herodotus relates that in their resentment these women vowed never to call their husbands by their names or sit at meat with them. He also mentions that the Ionian colonists themselves were not all Greeks, but partly Cadmeans, and it is probable that some of these came to Miletus. Diogenes

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[1] The temple was an imposing object at sea. Three splendid columns sixty-three feet high are still standing, a landmark to coasting craft. Chandler says, 'The memory of the pleasure which this spot afforded me will not be soon or easily erased. The columns, yet entire, are so exquisitely fine, the marble mass so vast and notable, that it is impossible to conceive greater beauty or majesty of ruin. At evening a large flock of goats returning to the fold, their bells tinkling, spread over the heap, climbing to browse on the shrubs and trees growing between the huge stones. The whole mass was illuminated by the declining sun with a variety of rich tints, and cast a very strong shade. The sea at a distance was smooth and shining, bordered by a mountainous coast, with rocky islands. The picture was as delicious as striking.'—*Ionian Antiquities.* There are portions of the temple now in the British Museum, including figures from the 'sacred way,' and a reclining lion of marble dedicated as the tenth of a spoil, and having the names of the dedicators inscribed on the back in archaic letters. The word 'Thales' [ƧΗ˥Α⊙] can be seen on the left end of the second line. It is much defaced, and written backward, for the inscription is *bostrouphedon*, the lines running alternately from left to right and right to left. Sir C. T. Newton does not think it applies to Thales, the son of Euxamius, but it might be that of a near relative. The date of these relics is about 570 B.C.—*Discoveries at Halicarnassus.*

[2] 'There from the fields where wild Mæander flows,
High Mycalé, and Latmos' shady brows,
And proud Miletus, came the Carian throngs,
With mingled clamours, and with barbarous tongues.'
POPE, *The Iliad*, Book II.

Laërtius informs us that, according to certain writers, Thales was of Phœnician descent, belonging to the family of the Thelidæ, who were among the most noble of the descendants of Cadmus and Agenor; but that a commoner statement represented him as a native Milesian of noble birth. It is possible to reconcile these accounts by assuming that the ancestors of Thales were among the Cadmeans who came from Athens to Ionia. They were the reputed descendants of Cadmus, son of Agenor, the Tyrian, who was said to have introduced the Phœnician alphabet into Greece, and whose followers in Bœotia ultimately became citizens of Athens. These Cadmeans intermarried with the Ionians of Miletus, and Thales, son of Euxamius and Cleobule, was in all probability a Milesian of Græco-Carian and Phœnician stock.[1]

Of his early life we have no particulars. As a babe he was probably dedicated to Apollo Uleus, the tutelary god of Miletus. Diogenes Laërtius remarks that he had no teachers except the priests of Egypt; but this may not refer to his primary education. His mother probably taught him the books of Homer, which were regarded in the light of a bible, among the older Greeks. It is uncertain whether public schools existed in his childhood, though we learn from Herodotus that Greece possessed excellent institutions of the kind 500 years before Christ. During one part of the day the boys were taught to read the poets, to write with the stylus, to reckon sums, to sing, and play upon the lyre. History, mathematics, and philosophy did not exist in the youth of Thales, and prose composition was apparently in its infancy. During the other part of the day the children went to another school, the palaestra or open air gymnasium; where, naked and anointed with oil, they practised running, leaping, wrestling, and throwing the discus, or the spear.[1] The wise Greeks attended equally to physical and to mental training. Figure dancing was also taught there, as a religious exercise in the festivals, for they believed with Plato that 'the gods, too, love sport.' At the age of sixteen it was customary to admit a youth to citizenship, by administering the oath of fidelity to the state.

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[1] There seems little foundation for supposing, as some do, that Euxamius and Cleobule quitted Phœnicia because of the tyranny, and settled in Miletus.

Diogenes Laërtius informs us that Thales was engaged in political affairs before he gave himself up to philosophy. The twelve cities of Ionia held a panegyris or annual festival at the Panionium, a field by the sea, on the north shore of Mycalé, where a temple to Neptune Heliconius, the national deity of the Ionians, had been erected.[2] Here sacrifices were offered, public games and dances were celebrated, poems were recited, and public business transacted by the envoys of the several states. Thales was, we believe, a visitor to the Panionium, and probably took part in the council. It is not unlikely that he also visited the greater gathering at Delos, of which the hymn ascribed by Thucydides to Homer gives an admirable picture.[3]

Herodotus tells us that Thales, foreseeing the rise of the Lydian power, advised the Ionians to form a confederacy with a common council at Teos, a central city of the group, where they could discuss matters affecting the general safety.[1] But this excellent suggestion was not adopted, and the optional alliance of the Panionium, which was based on community of race, language, and faith, broke down before the advance of Crœsus, and ultimately led to the ruin of Ionia.[2]

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[1] A gymnic agon or contest appears to have been instituted at Miletus in connection with the Didymean legend. (See Chandler's *Ionian Antiquities*.)

[2] The site was probably that of the modern village of Tchanglé, where Sir W. Gell found an inscription marked 'Panionium.' (See Leake's *Asia Minor*.)

[3] 'Here oft in flowing robes the Ionians throng,' etc. Grote allows its date to be at least 600 B.C.

The conquest of Ionia did not happen, however, until the old age of Thales. It was heralded by events occurring during the youth of the philosopher, when Sadyattes, King of Lydia and ancestor of Crœsus, made war against Miletus during the last seven years of his reign (624–617 B.C.), and bequeathed the quarrel to his son Alyattes, who harried the fields and gardens without the walls to the music of the flute and harp. The temple of Minerva at Assesus, a small town dependent on Miletus, was accidentally burnt by his soldiers; and Alyattes, being stricken with illness, sent messengers to Delphi to inquire what he should do to recover. The oracle answered that he should rebuild the temple; and Alyattes accordingly despatched his envoys to Miletus to arrange a truce for that purpose. But Thrasybulus, the tyrant of Miletus, with whom 'Thales lived,'[3] getting wind of their errand, displayed a great quantity of stores in the market-place, and so impressed the envoys with the provision of the town, that Alyattes not only rebuilt the temple, but raised the siege, and concluded a peace.[4] It may be added that about the same period (630–610 B.C.), Ionia was alarmed by the incursions of Scythian and Cimmerian nomads into Asia Minor from the north. Among their other depredations they plundered the city of Magnesia, on the Meander, and threatened the temple of Artemis at Ephesus.

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[1] Herodotus, i. 170.

[2] About 547 B.C., when Cyrus conquered Crœsus.

[3] Diogenes Laërtius.

[4] Herodotus, i. 20, 23.

Plutarch tells us that Thales was said to have engaged in commerce, like Hippocrates the mathematician. In those days, as Hesiod informs us, no business was looked upon as derogatory, and trade was an honourable profession, 'as it brought home the produce of barbarous countries, engaged the friendship of kings, and opened a wide field of knowledge and experience.'[1] Solon, the Athenian lawgiver, applied himself during his early life to merchandise, the rather to gratify his curiosity and extend his information, than to get rich. Plato, also, carried oil to Egypt, and thus defrayed the expenses of his travels. That country had been opened up to Grecian commerce by Psammitichus, who owed his crown to the assistance of Ionian arms. In the time of Thales, the city of Naukratis was a privileged port for Grecian traders. It stood on the eastern bank of the Canopic or western mouth of the Nile, not far from the royal city of Sais. Here the Greeks possessed a fortified warehouse, or 'Pan-hellenion,' as well as temples to their gods, including one to Apollo, erected by the Milesians.[2] It is probable that Thales landed at Naukratis, and proceeded to Sais, where he could confer with the priests. Like Solon, he may also have visited Memphis and Heliopolis. Egypt, with its ancient civilization, was a land of wonders and a revelation to the early Greek. The fertility of its soil, the mystery of its river, the customs of its people, astonished him as much as the majesty of its pyramids

[1] Plutarch's *Life of Solon*.

[2] Fragments of this temple are now in the British Museum. They were discovered by Mr. Flinders Petrie, who unearthed the remains of Naukratis near the modern village of El Gaief. The first temple of Apollo and the Pan-hellenion probably date from 620–610 B.C., if not earlier. Fragments of votive bowls, offered by Greek travellers, were also found, some bearing well-known names, such as Rhœcus the sculptor. (See *Naukratis*, by *W. F. Petrie.)*

and temples, the learning of its priests, and the splendour of its court. Everything was so different to what he had been accustomed, that we can only compare his feelings with those of the first Europeans who visited China or Japan. Moreover, he had much more to learn from Egypt than he had to teach. The Egyptians were well advanced in the mechanical arts and in agriculture. They possessed a knowledge of science, especially of medicine and mathematics. Owing to the annual inundations of the Nile obliterating the boundaries, geometry had been applied to land surveying; and the unclouded skies had facilitated the study of astronomy. Thales is said to have learned geometry in Egypt, and to have found the heights of the pyramids by measuring their shadows. Proclus informs us that he introduced this learning into Greece, and extended it, both in the abstract and applied sense, by theorems of his own invention.[1] What he otherwise learned we are unable to say; but Solon, his contemporary, is reported to have conversed upon philosophy with Psenophis the Heliopolitan, and Senchis the Saite, 'the most learned of the Egyptian priests,' and to have heard from them an account of the lost continent of Atlantis, which some have supposed to be the Canary Islands, and others America.[2] Pythagoras also went to Egypt in order to confer with the priests. Aristotle is of opinion that Thales was indebted for part, at least, of his education in astronomy to the Chaldeans. As early as the 8th century before Christ, there were astronomical observatories in most of the large cities of the Euphrates valley, and professional astronomers sent in their reports to the King of Assyria. From a cuneiform inscription found in the palace of Sennacherib at Nineveh, we learn that eclipses both of the sun and moon were then predicted.[1] It is not incredible, therefore, that, as Herodotus reports, Thales was able to foretell the solar eclipse which happened during a great battle between the army of Alyattes, King of Lydia, and Cyaxares, King of the Medes.[2] The historian records that the day suddenly turned to night, and put an end to the action; whilst the fears of the combatants, who probably saw in it a divine portent, led to a peace which was ratified by the marriage of Aryenis, daughter of Alyattes, to Astyages, son of Cyaxares.

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[1] *The Commentaries of Proclus*, who flourished about A.D 412.

[2] Plutarch's *Life of Solon.*

Thales had foretold the year of this eclipse to the Ionians, but probably not the locality. Chronologists are at variance in fixing the date, some placing it as early as 625 B.C., and others as late as 583 B.C.; but since the investigations of Airy, Hind, and Zech, the 28th of May, 585 B.C., is commonly accepted.[3] This agrees with the selection of Des Vignoles, and the statement of Cicero, who places it in the reign of Astyages in the 48·4 Olympiad, or about 585 B.C.[4]

This prediction of Thales appears to have created a profound impression on the Greeks, and, while shaking their faith in omens, it probably stimulated their interest in natural science.

About this time he received the designation of 'Sophos,' or wise man. It was, we are told, conferred on Thales the first, during the archonship of Damasius at Athens,[1] 585–3 B.C. According to the best authorities, Solon of Athens, Bias of Priene, Pittacus of Mitylene, Chilon of Lacedæmon, Cleobulus of Cnidus, and Periander of Corinth were the others who made up the Seven Sages; but Plato substitutes Myson of Chêne for Periander, because the latter was a tyrant, and therefore unworthy of the name of wise.

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[1] Herodotus, i. 74, 103. Xenophanes, an Ionian, who flourished not much later than Thales, confirms Herodotus.

[2] G. Smith, *Assyrian Discoveries*, p. 409.

[3] Sir G. Airy, *Phil. Trans.*, vol. cxliii. p. 179.

[4] *De Divinat*, i. 49. Pliny, ii. XII. This date, however, makes Herodotus wrong in assigning the eclipse to the reign of Cyaxares, who probably died 594 B.C. Mr. Page, author of *New Light from old Eclipses*, has, by Ptolemy's canon and a lunar computation, fixed the time as 5h. 24m. 11s. on the morning of the 8th *July, 597 B.C.*

The title was due rather to the shrewd moral sentences of these men, and to their political ability, than to any knowledge of natural science, for Thales alone had speculated in this direction, and the term philosophy did not come into vogue until Pythagoras, who belonged to the next generation.

Their modesty in sending the famous tripod to one another contributed greatly to their honour. The story goes that certain strangers from Miletus, meeting with some fishermen of Cos, bought a cast of their net beforehand, and when it was found to contain a golden tripod—believed to be that thrown into the sea by Helen on her way from Troy—a dispute arose about the ownership which threatened to involve the two states in hostilities. They appealed to the oracle of Apollo, which directed them to give the tripod to the wisest, and it was sent to Thales, who in turn passed it to Bias, and thus after going the round of them all it came back to Thales, and was dedicated to Apollo.[2]

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[1] Zeller puts the date 586 B.C.; Bretschneider, 585–583 B.C. The second Damasius is evidently meant. Thales was then about 56.

[2] The story is varied in every particular. We have followed the version of Plutarch, who says it was sent to the Ismenean Apollo at Thebes; but others have it the Delphic, and the Didymæan, which seems the likeliest, being so near Miletus. The origin of the tripod is also diversely given, it being, according to one account, the jetsam of a wrecked ship sent by Periander to Thrasybulus. The locality, too, is varied, and the order of presentation. Again, it is said to have been a goblet weathed by one Bathydes or Bathycles, and a cup presented

The story is so diversified that, whatever its foundation, it shows the Greeks were in some doubt as to who was the wisest, though Thales appears to have the best of it.

Pausanias relates that the Seven Sages met at Delphi and offered several of their best mottoes to the god.[1] The following were inscribed in letters of gold on the vestibule of the temple:—

> Know thyself.
> Nothing too much.
> Know thy opportunity.
> Suretyship, then ruin.

There is confusion in the authorship of their wise sayings, but the first of these is ascribed to Thales, and is perhaps the most pregnant of them all. The second is usually attributed to Solon,[2] the third to Pittacus, and the fourth to Chilon.[3] Periander is also reported to have said, 'Practice does everything;' Bias, a lawyer, is responsible for 'Most men are wicked;' and Myson was wont to say that 'Words were made for things, not things for words.'

They are said to have all met, excepting Thales, at the court of Crœsus and at the Panionium, near Priene, as well as at Corinth, where they were the guests of Periander. Plutarch, in his *Banquet of the Seven Sages*, has given us a more or less imaginary account of the latter symposium, to which he introduces one Niloxene of Naukratis, who had known both Thales and Solon during their stay in Egypt, and who had been sent by Amasis, king of that country, with a

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by Crœsus. (See Diogenes Laërtius, *Lives of the Philosophers*, and Plutarch's *Life of Solon*.)

[1] Pausanius, book x. 24; Grote, however, says the mottoes were inscribed later.

[2] Also to Cleobulus and Chilon—'a middle course is best.' (See *Clement of Alexandria*.)

[3] *Also to Thales*, (See Clement of Alexandria.)

series of 'posers' for Bias to answer—Thales having offended Amasis by his remark that it was a surprising thing to see 'an old man a tyrant.' Thales declares that he used the word 'pilot,' not 'tyrant';[1] but nevertheless, as the young man said when he aimed at his dog and hit his mother, 'the stroke is not lost.' At supper they recline on couches, including Melissa, wife of Periander, but excepting Cleobuline, daughter of Cleobulus, who sits. After the repast Melissa distributes floral crowns to her guests, libations of wine are offered to the gods, and airs performed by the flute-players. Then come the questions of Amasis, to which Thales replies: that the oldest thing is God, for He is increate; the greatest is space, for it contains all; the most beautiful, the world; the wisest, time, for it discovers all; the commonest, hope, for it abides with those who have nothing; the most useful, virtue, for it turns all to profit; the most harmful, vice, for it corrupts all it touches; the strongest, necessity, for it is invincible; the easiest to follow, nature, for even pleasure cloys. To another question, 'Which is the happiest city?' Thales answers, 'That in which the citizens are not too rich or too poor.' On being asked, 'Which is the best house?' he replies, 'That which gives least concern to its master.' After this Melissa and Cleobuline withdraw, and the loving cup goes round.[2]

We have quoted these sayings partly to show the kind of questions the sages were expected to answer, and partly because Diogenes Laërtius also gives some of them as authentic. The same author represents Thales as answering to the question, 'Who is happy?' 'He who is healthy in his body, easy in his circumstances, and well instructed as to his mind.' When asked how men might live virtuously, he replied, 'By never doing ourselves what we blame in others.' A person wished to know whether a wrongdoer could escape the notice of the gods. 'Not even if he thinks wrong,' answered Thales. He said there was no difference between death and life, and when he was asked, 'Why then do you not take your life?' he retorted, 'Because it makes no difference.' Another saying of his is that men ought to remember the friends who are absent as well as those who are present, and that they should care rather to beautify their minds by study than to adorn their faces. He is said to have left no writings; but he is believed to have composed about two hundred verses, of which the following lines are preserved:—

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[1] Amasis began to reign about 570 B.C.; therefore, if Thales had not visited Egypt before, he must have been about 70 at the time.

[2] A bust (probably fictitious) in the museum of the Vatican at Rome represents Thales as a man of strong, handsome, firm-set features, wearing his hair (presumably dark) in short wavy locks, with a well-trimmed beard and moustache.

> 'Many words are not a sign of wisdom; breathe, rather, one wise thought; select one worthy object; so shall you best reprove the endless prating of fools.'

Thales, as we learn from Herodotus, mistakenly attributed the rise and fall of the Nile to the Etesian or north winds blowing against the current. That historian also credits him with having advised Crœsus, King of Lydia, to cross the River Halys by diverting a portion of the stream into an artificial channel, thus forming two fordable branches. But as Crœsus began his campaign against Cyrus 548–546 B.C., Thales must have been extremely aged, and not likely to be in Crœsus's camp, though he may have sent word to the latter, who was then suzerain of Ionia. Several writers attest the story; but Herodotus himself thinks that Crœsus passed the river by the bridges which existed *in his day.* Sir Henry Rawlinson remarks that the

Kizil Irmak, or ancient Halys, is even now spanned by two bridges at Bafra, where the channel splits at a point agreeing with that crossed by the king. Did the double channel there give rise to the story of Thales, who may indeed have recommended that point, or is it the remains of the work executed by Crœsus at the instance of the Milesian? Cyrus we know was successful in the struggle, and Bias of Priene is said to have counselled the Ionians to retire to Sardinia; but this advice was neglected.

Thales is recognised as the father of Grecian geometry, astronomy, and philosophy. Several theorems are attributed to him: for instance, that a circle is bisected by its diameter, that a semicircle contains a right-angled triangle, that the angles at the base of an isosceles triangle are equal, that the three angles of a triangle are equal to two right angles, and that the sides of equiangular triangles are proportional. The latter theorem was probably used by him in his determination of the distance of a ship at sea.

Besides founding the geometry of lines, and the measurements of heights and distances, he predicted the solar eclipse, he determined the diameter of the sun to be $\frac{1}{720}$ part of the zodiac,[1] he divided the year into 365 days, assigning thirty days to each month. He also discovered the Lesser Bear, and advised his countrymen to steer by it, as being nearer to the pole than the Great Bear. Plutarch has stated that Thales knew the earth was globular; but this appears to be doubtful, for most of his successors considered it a flat disc. The sphericity, in fact, was one of the doctrines of Pythagoras.

Thales taught that water was the elemental fluid, and the material source of all things.[1] Aristotle declares that the early physicists did not separate the material cause from the creative mind; and as we are told that Thales supposed all things to be full of gods or dæmons, and that the lodestone, or excited amber, possessed a 'soul,' it would seem that he regarded the 'forces of Nature' as present deities. The doctrine of Thales was interpreted by his pupils and successors, Anaximander selecting as the primal element, or 'principle,' a hypothetical body, between fire and air on one hand, and earth and water on the other.[2] Anaximenes chose air, while Heraclitus adopted fire. All the four, though differing in particulars, asserted that the whole variety of things arose from the transformations of one simple element. It is not our purpose to trace the progress of the philosophic schools, which, with the exception of the Pythagorean, thus originated. Nor can we add much to the meagre statement of Thales' familiarity with the phenomenon of frictional electricity and magnetism. Amber, a fossil resin, of sunny lustre, probably received its name *elektron* from Ἠλεκωρ, the sun-god. It was prized as a gem, and Homer speaks of a 'gold necklace hung with bits of amber,'[3] as being among the jewels offered by the Phœnician leaders to the Queen of Syra. According to the myth of the Heliadæ, the sisters of Phaëthon, amber was the tears they shed when their brother was hurled by the lightnings of Zeus into the river Eridanus. The Eridanus, flowing into the north sea, is mentioned by Herodotus as a source of amber. It was also found in Liguria, and perhaps in Sicily, as well as the coasts of the Baltic, from which places the Phœnicians probably conveyed it. The lodestone, which was classed with amber for its attractive property, was obtained at Heraclea in Lydia, and hence called the Heraclean stone; but its later name of magnet (μάγνης) came from Magnesium on the Meander, or from Magnesium at Sipylos, where it was also found.[1]

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[1] This is accepted as the meaning of the passage in Diogenes Laërtius, 'that he defined the magnitude of the sun as being 720 times as *great as the moon*.'

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[1] Compare 'the waters' mentioned in Genesis. Had Thales a knowledge of the Jewish or Phœnician cosmogony?

[2] There is a stone bearing the name of Anaximander in the Lycian room of the British Museum.

[3] *Odyssey*, XV.

In devoting himself to philosophy, Thales declined to marry. When his mother urged him to take a wife, he at first said, 'It is too soon,' and some time afterwards, 'It is too late.' Plutarch relates that Solon, when he visited Thales at Miletus, expressed a wonder that he did not raise a family. Thales made no immediate answer, but instructed a stranger to say that he came from Athens ten days before. On Solon inquiring the news, the man said there was none, except the funeral of a young man, the son of a very distinguished man, called Solon. At this, Solon gave way to his grief; and Thales, taking him by the hand, said, with a smile: 'The things which crush so firm a man as Solon kept me from marriage; but be of good cheer, the news is false.' Plutarch justly observes that fears of this kind are not sufficient grounds for a life of celibacy, and points out that Thales himself appears to have felt the want of something to love, for he is said to have adopted his sister's son, named Cybisthus.[2] Nevertheless, the cares of a family have frequently deterred men of a solitary and studious turn from marriage. We gather that he was poor; and when he was twitted with the uselessness of that knowledge which brought him no wealth, he answered, in his practical way, by leasing some olive gardens which he foresaw would yield an abundant crop. By this means he is said to have acquired a large sum, which, however, he returned to the owners, thus demonstrating that his object was to discover the truth for its own sake, and not for personal profit. It is also related that Mandretus of Priene, one of his pupils, asked Thales how he best could show his gratitude for the excellent precepts he had received, and Thales replied: 'When you are teaching others, tell them that Thales was the author of the doctrine. This will show a commendable modesty in you, and be a rich reward to me.'[1]

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[1] The castle hill at Magnesium ad Sipylum is, according to Dr. Chishull, magnetic. (See his *Travels in Turkey*, 1747.) Lodestone, or magnetite, is the magnetic oxide of iron, $FeOFe_2O_3$.

[2] Some were of opinion that Cybisthus was Thales' own son; it is said he ultimately married an Egyptian poetess. (Diogenes *Laërtius.*)

It is related that when he was very aged, and being led out of his house by Thratta, his old maidservant, one evening to watch the stars, he fell into a ditch and bewailed himself, on which the woman cried, 'How can you, O Thales, expect to view the stars in heaven, when you cannot see what is under your feet?'[2]

He is said to have died, overcome with heat and thirst, while a spectator of the Milesian games, at the age of ninety-two or so.[3] 'To those who run in the stadium the prize is in the end of the race; to those who labour in wisdom the reward is in old age.'[4]

Plutarch informs us that by his own wish he was buried in a neglected part of the Milesian fields, and predicted that it would become the market-place.[5] An inscription placed upon his tomb reminded the passer that although it was lowly, the fame of Thales ascended to the skies. His statue was erected by the Milesians, and bore the words: 'Miletus, fairest of Ionian cities, gave birth to Thales, great astronomer, wisest of mortals in all kinds of knowledge.'

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[1] Given in the *Lives and Most Remarkable Maxims of the Ancient Philosophers*. (Lon. 1726.)

[2] Diogenes Laërtius: Hippolytus' *Refutation of all Heresies*.

[3] If he lived to the 58th Olympiad (Diogenes Laërtius), he would be ninety-two at least, 548–547 B.C.

[4] Demophilus: *The Pythagoreans*.

[5] Plutarch's *Life of Solon*.

The site of Miletus is now buried under the silt of the Meander, which has partially filled up the Latmian Gulf; and it is conjectured that a hillock now seen in the plain was once the island of Ladé; but the day is coming, perhaps, when its ruins will be disinterred by the help of that power which revealed itself to Thales in the amber.

WILLIAM GILBERT.

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WILLIAM GILBERT, or, as he wrote it, Gilberd, was born in the parish of Trinity, Colchester, in or about the year 1540. His father, Hierom (or Jerome) Gylberd, was a native of Clare, in Suffolk, where, as the antique Fuller expresses it, his family 'had resided in a gentile equipage some centuries of years.'[1] Hierom Gylberd removed to Colchester, where he was admitted a free burgess of the town in 1553, and rose to be the Recorder. Two of his four or five sons were named William, but the subject of our sketch was the eldest. Nothing is known of his boyhood, but he is said by Morant to have studied at both Oxford and Cambridge.[2] It is certain that he was entered at St. John's College, Cambridge, in May, 1558, and took his degree of B.A. two years later. On the 21st March, 1560–1, he was elected a Symson fellow of his college, and took his degree of M.A. in 1564. He was mathematical examiner at the college in 1565 and 1566, and senior bursar in 1569. The same year he took his degree of M.D., and on December 21st was made a senior fellow.

After leaving the University he travelled on the

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[1] *The Worthies of England*, 1662. Fuller's authority was a near kinsman of Gilbert's, namely, William Gilbert of Brental-Ely, Suffolk.

[2] *History and Antiquities of the most ancient Town and Borough of Colchester.* By P. Morant, 1748. Morant says that Thomas Gilberd, his great-grandfather, was born at Hinticlissham, Suffolk, and was made a burgess of Colchester in 1428.

Continent, but returned to London in 1573, and began the practice of medicine. He was elected a Fellow of the Royal College of Physicians in the same year, and held the office of censor from 1581 to 1582, and twice afterwards. He was Treasurer of the college from 1587 to 1591, and subsequently Consilarius from 1597 to 1599, and finally President in 1600, the date alike of his great work and his appointment as Chief Physician to the Court of Queen Elizabeth. For some time he had been one of the physicians in ordinary to the Queen, and resided on St. Peter's Hill, near to St. Paul's, and between Upper Thames Street and Little Knight Rider Street, where he seems to have entertained a kind of society or group of in-door patients, if we may judge from a letter of Mr. John Chamberlain, who lived with him, addressed 'To my very goode frend Mr. Dudley Carleton geve these, at The Haghe or elsewhere.' In this letter Chamberlain remarks that 'The covie' (*i.e.* covey) 'is now dispersed, and we are driven to seeke our feeding further of, our Doctor being already setled in Court, and I redy to go to Askot.'[1] It is clear from Chamberlain's letters that Gilbert broke up his home on St. Peter's Hill, and removed to the Court about the middle of February 1600.

He was the scientific star of Elizabeth's glorious reign, and one of the first experimentalists that England has produced. While Bacon was only thinking about his *Novum Organum*,[2] in which he advocated the inductive method of research, Gilbert was employing it with magnificent results.

On the death of the queen in March 1603, he was retained in his office by James I., but did not long survive his royal mistress. He died on November 30th of the same year, some say at Colchester, where he owned a house known as Tymperley's or Tympernell's, which is still to the fore, near the Church of the Holy Trinity, where he is buried.[1] His tomb is in the chancel, and bears a Latin inscription, attributed to his brothers Ambrose and William, setting forth that he composed a book concerning the magnet, celebrated among foreigners, and that his age was sixty-three.

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[1] *Letters of John Chamberlain.* One addressed to Sir Dudley Carleton (afterwards Lord Dorchester), and dated February 3, speaks of Gilbert being appointed, but not yet sworn. That quoted is dated February 24.

[2] The *Novum Organum* was published in 1620.

The celebrated treatise, *De Magnete Magneticisque Corporibus, & De Magno Magnete Tellure, Physiologia nova* ('Of the Magnet and Magnetic Bodies, and that great Magnet the Earth'), was published as a folio at London in the year 1600. It is the treasury of Gilbert's fame, and contains an account of his numerous experiments in electricity and magnetism, and his great discovery that the earth itself is a globular magnet.

Since the age of Thales, more than two thousand years before, very little had been added to the science of rubbed amber and the lodestone. Theophrastus (321 B.C.) and Pliny (70 A.D.) mention another stone, the *lapis lyncuris*, of a fiery red colour, which, after friction, attracted straws like the amber. It has been thought a species of tourmaline, but with little reason, and it may have been only a deeper variety of amber, or some other red mineral. The electric ray, or torpedo, as we learn from Pliny, was known to stun its victims; and it is said that Anthero, a freedman of Tiberius, was cured of gout by a shock from the animal.

We are also informed that Wolimer, King of the

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[1] This house may be his birthplace, inherited from his father. (*See Morant's Hist. and Antiq., etc., ante.*)

Goths (415 A.D.), emitted sparks from his person.[1] It does not appear, however, that these effects were al referred to the same agency.

With regard to the lodestone, Lucretius informs us that it communicated its power to iron rings in contact with its poles; and that iron filings in the bottom of a brass vessel rose up and 'raved' when a magnet was moved under them, though the wall of brass intervened. During the Middle Ages facts like these were mingled with the fables of magic in such a manner that it was difficult to know where truth began and ended. Thus the lodestone was accused of producing melancholy, of making love philtres, of being a test of female chastity, of losing its power when rubbed with garlic, and regaining it when smeared with goats' blood, of declining to attract iron in presence of the diamond. Gilbert discarded all these fables, and appealed in a strict and rational manner to the test of experiment. He sifted the grain of electrical and magnetic phenomena from the chaff of mediæval phantasy and legend, and laid the foundations of a true science.

He discovered that a great many materials besides amber had the power of attracting light things after being rubbed; whilst others did not appear to possess it. He proved this by holding the excited body towards a pivoted needle or index, as an improvement on the straw employed in the observations of the ancients. Gilbert called those materials which were excited by friction electrics, coining this new term from the Greek *elektron,* signifying amber, and thus naming the science to all future time. Glass, jet, sulphur, sealing-wax, resin, diamond, sapphire, opal, amethyst, and other crystals, he found to be electrics; while marble, ebony, ivory, flint, emerald, pearl, coral, and the metals proved non-electric. We know now, by more refined experiments, that all bodies are capable of becoming electric by dint of friction if they are properly insulated. Gilbert was unaware that another property, that of *conducting* electricity, came into play during his experiments, and that though metals, for example, can be electrified by friction as well as glass, they require to be *insulated* from the hand in order to show it by his arrangement; for, being conductors, the electricity would otherwise escape to earth through the body of the experimenter. Amber, glass, and sealing-wax being non-conductors, or insulators, the electricity excited on them keeps its place, and influences the needle. Some substances, too, are briskly, while others are feebly, excited by a similar friction. Gilbert noticed that dry weather and a northerly wind were favourable to his experiments, whereas, moist weather and a southerly wind were against them; but, not knowing that water is a conductor, he did not suspect that by condensing on the cold surface of the electric it allows the electricity to escape to earth. Gilbert also found that an electrified body attracts the particles of smoke when plunged into it; and it is interesting to note that of late years the fumes of certain lead-works have been deposited by electrifying them.

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[1] Eustathius.

The results of these experiments are described in *De Magnete*, along with his magnetic observations. Turning to the latter, we should premise that before Gilbert's time the mariner's compass was in general use. It was known in Europe during the 12th century, and is supposed to have come from China by way of Arabia. But more proof is required of the Chinese claim to its invention. The first European compass was merely a piece of lodestone floated in a vessel of water, so that it pointed nearly north and south. The pivoted needle was of a later origin; and even that had no graduated card at one time. As for the science of magnetism, it was almost as backward as that of electricity in Gilbert's day, though it was beginning to attract attention. An Arabian chemist, Abou Moussa Geber ben Hajjan, who flourished in the 8th century, had shown, it would appear, that lodestone could lose its natural force. Georg Hartmann, Vicar of St. Sebaldus, in Nuremberg (1489–1564), had discovered the 'dip' of the magnetic needle; and Robert Norman, a maker of compasses in London, devised the 'dipping-needle,' and printed an account of it in his *Newe Attractive*, a black-letter quarto, dated London, 1581. Norman's work did not escape the notice of Gilbert, who distinguished the attraction of the lodestone from that of the electrics. He claimed that earth and other materials besides iron were attracted by the lodestone. He thrust a magnetised needle through a spherical float, and immersed the whole in water, so that the magnet took up the position of the dipping-needle. Most important of all, he concluded, from numerous experiments, that the needle behaves as it does because the earth itself is a vast globular magnet; and he constructed a spherical magnet or *terella* out of a piece of lodestone, with which to illustrate the dip and declination of the mariner's compass.

'The magnet,' says Gilbert in his original work, 'is wonderful in innumerable experiments; and, as it were, a living force. . . . The ancients, the whole Platonic school, the Egyptians, and Chaldeans, affirm that the universe is endowed with life. . . . I myself think that the whole creation, all globes, all stars, and the glorious earth itself, are governed from the beginning by a proper and determinate life, and have their movements of self-preservation. Although the are not in the stars, the sun, or the planets any organs which can be recognised by us, yet they live. If there be anything of which man can boast, assuredly it is life; and God Himself (by whose will all things are ruled) is intelligence, is mind.'[1]

In a letter to his friend the Rev. William Barlowe, Archdeacon of Salisbury, Gilbert says that 'there is heere a wise, learned man, a secretary of Venice, he came sent by that state, and was honourably received by Her Maiesty. He brought me a Lattin letter from a gentleman of Venice that is very well learned, whose name is Johnnes Franciscus Sagredus; he is a great magneticall man, and writeth that hee hath conferred with divers learned men of Venice, and with the readers of Padua, and reporteth wonderful liking of my booke. You shall have a copy of the letter. Sir, I propose to adioyne an appendix of six or eight sheets of paper to my booke after a while (I am in hand with it), of some new inventions, and I would have some of your experiments in your name and invention put in it, if you please, that you may be knowen for an argumenter of that art.'[2] This letter was probably written on the 14th February, 1602; but the promised edition of the work never appeared. The inventions referred to are perhaps the nautical instruments for finding the latitude without 'the help of the sun, moon, and stars,' which are described by Gilbert's friend, Thomas Blondeville, in a quarto volume published in 1602, and entitled, *The Theoriques of the Seven Planets, shewing their diverse motions, and all other accidents called Passions thereunto belonging.*

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[1] Dr. B. W. Richardson, from *De Magnete.*

[2] *Magneticall Advertisements, or divers pertinent Observations and approved Experiments concerning the nature and properties of the Load-stone.* W. Barlowe, 1616.

Barlowe states, in the preface to his *Magneticall Advertisements*, that he had received many other letters from Gilbert, but they were all gone.

Galileo was probably one of the learned men of Venice and Padua who had praised the *De Magnete*, for he has written of it, 'I extremely admire and envy the author of *De Magnete*. I think him worthy of the greatest praise for the many new and true observations which he has made, to the disgrace of so many vain and fabling authors; who write not from their own knowledge only, but repeat everything they hear from the foolish and vulgar, without attempting to satisfy themselves of the same by experience; perhaps that they may not diminish the size of their books.'[1] On the other hand, Bacon characterized it as a 'painfull (*i.e.* painstaking) experimentall book;' but, at the same time, 'an instance of extravagant speculation founded on insufficient data;' a remark which, though in the main unjust, had perhaps a tinge of truth.[2]

De Magnete is a very scarce work, having never been reprinted since 1638, or translated into English. But, towards the end of 1889, a 'Gilbert Club' was formed in London, for the purpose of issuing a translation of the work in imitation of the original folio, and of celebrating the tercentenary of its first publication.

Morant states that Gilbert left a manuscript entitled *De Mundo nostro Sublunari Philosophia nova*, which was preserved in the library of Sir William Boswell, Kt., and published as a quarto at Amsterdam, in 1651.

Gilbert bequeathed his books, instruments, and minerals, including doubtless his lodestones, to the

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[1] Drinkwater's *Life of Galileo.*

[2] *Novum Organum*, 1620.

College of Physicians; but these were consumed, with the college, at the foot of Amen Corner, in the great fire of 1666. He left his portrait to the Schools Gallery at Oxford. It is said to have represented him holding a *terella* or earthkin in his hand, and was inscribed over the head with the date 1591, 'æt. 48.' If his tombstone be correct, however, he was 51 years old at that time. The Bodleian Library portrait, engraved in 1796, may have been copied from this picture; but, judging from the extant engravings, it does not appear to be a fac-simile. It gives a half-length view of Gilbert, with his right hand resting on a terrestrial globe. He wears a physician's gown over his doublet, an ample ruff, and a high-crowned beaver hat. His features show a trifle small, but are not unpleasing; the eye is calm, clear, and staid, and the brow where visible is wide and full.

Quaint old Fuller says, that Gilbert 'had (saith my informer) the *clearness* of *Venice glass*, without the *brittleness* thereof; soon *ripe* and long *lasting* in his perfections. He commenced doctor in physick, and was physician to Queen Elizabeth, who stamped on him many marks of her favour, besides an annual pension to encourage his studies. He addicted himself to chemistry, attaining great exactness therein. One saith of him that he was *stoicall*, but not *cynicall*, which I understand *reserv'd* but not morose; never married, purposely to be more beneficial to his brethren, such his *loyalty* to the queen, that, as if unwilling to survive, he dyed in the same year with her, 1603. His stature was tall, complexion cheerful, an happiness not ordinary in so hard a student and retired person. He lyeth buried in Trinity Church, in Colchester, under a plain monument. Mahomet's mb at Mecha is said strangely to *hang* up, attracted by some invisible loadstone; but the memory of this doctor will never *fall to the ground*, which his incomparable book, *De Magnete*, will *support* to eternity.'[1]

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[1] *Worthies of England.* Thomas Fuller, D.D. London, 1662.

BENJAMIN FRANKLIN.

BENJAMIN FRANKLIN.

THE forefathers of Benjamin Franklin lived on a freehold of thirty acres, and kept a smithy, at the village of Ecton in Northamptonshire. Francquelin is a French name, but the word meant a yeoman in Chaucer's time, and it is doubtful whether his ancestor came from France, or was called Francklyne from his lot in life. The place continued in the family for at least three hundred years, and was inherited by Franklin's uncle Thomas, who, according to the custom, was bred a blacksmith, to carry on the business, but studied for the Bar, and became a leading man in the county. His character is said to have resembled that of his more distinguished nephew, Benjamin. Another uncle was bred a silk dyer, and, being of an ingenious turn, devised a system of shorthand, which, while in America, he taught to his young godson, who, as usual, forgot it. He also composed many fugitive poems, which were never printed; took down the ablest sermons he heard in shorthand, and collected volumes of political pamphlets. Josiah, the father of Franklin, was also bred a dyer; but, having joined the Nonconformists, like his brother Benjamin, and their conventicles being forbidden by law, he emigrated about 1685 with his wife and three children to New England, where he adopted the trade of tallow chandler and soap boiler. Here he found the
us freedom which had been denied to him in
d, and being a man of prudent character and
judgment, he succeeded in the new colony.

He never took any part in public affairs, but his advice was sought by the leading men, as well as by private persons, who often called on him to arbitrate in their contentions. For the rest, he was handy with tools, could draw well, played the violin, and sang a good song.

His first wife died, leaving him with a young family of seven, and he married Abiah Folger, daughter of Peter Folger, one of the first settlers of New England, whom Cotton Mather styles 'a godly and learned Englishman,' and who composed several works, one of which asserts the liberty of conscience in doggerel verse. She added ten children to the flock, making seventeen in all, and Franklin remembered seeing thirteen of them sitting at table, who all grew up and were married. Both his father and mother were strong and healthy, and lived to a great age.

Benjamin, the fifteenth child, and the youngest son of a youngest son for five generations, was born at Boston, in New England, on January 6th (O.S.) or 17th (N.S.), 1706. His elder brothers were all put to trades, but he, being the tenth son, was dedicated by his father to the ministry, and sent to a grammar-school at the age of eight. He had already learned to read, and before the end of a year was dux of his class; but his father, burdened by his large family, gave up the idea of the Church, and placed him at another school, kept by Mr. George Brownwell, under whom he learned to write a good hand, but failed in arithmetic. This was all the schooling Franklin ever had, for when he was ten his father took him to serve the shop, run errands, and cut the wicks for making candles.

He disliked this work, and had a strong inclination for the sea, which his father opposed. Living near the water, he learned to swim and handle a boat. The child is father of the man, and Ben was the leading spirit among his playfellows. Part of the millpond where the boys used to fish for minnows was bounded by a salt-marsh, which got trodden with their feet into a quagmire, and Ben, for the general good, proposed that they should build a pier to stand on with some stones intended for a new house. The boys toiled like emmets, and the pier was built; but of course the stones were missed, and an inquiry was made. 'We were discovered,' says Franklin, 'complained of, and corrected by our fathers; and though I demonstrated the utility of our work, mine convinced me that that which was not honest could not be truly useful.'

Franklin was blessed with a good father, and owed a great deal to his early training. He turned the table-talk on subjects likely to improve his children, and so little notice was taken of the dishes that, even in after life, Franklin was indifferent to the kind of food he ate, and found the habit serviceable. The long graces of his father before and after meat were, however, a great weariness to Ben, and on one occasion, when they were salting their winter store of provisions, the boy exclaimed: 'Father, could you not say grace over the cask, once for all? it would be a vast saving of time.'

Besides his boyish love for the sea, Franklin had a passion for reading, and spent his pocket-money in books, especially on voyages and travels. He read Bunyan's works, most of his father's books on divinity, Burton's *Historical Collections*, Plutarch's *Lives*, Defoe's *Essay on Projects*, and Mather's *Essay to do Good*. Doubtless, his mind drew its own nourishment from them all; but he was alive to having profited by the last three works.

Seeing his thirst for knowledge, his father bound him apprentice to the printing trade with James, his elder brother, who had started in Boston. Franklin liked this better than chandling, and read more than ever, often sitting up the better part of the night. Cast in a new town on the edge of the backwoods, his means were slender; but he was wise to use them. His ingenuity and diligence supplied the place of fortune and education. He borrowed books, taught himself arithmetic and a little geometry; he studied logic, and practised the Socratic method on his friends, retaining to the last a modest manner of persuasion. He adopted a vegetarian diet, and thus saved money to buy books, as well as time to read them during the dinner hour; but he afterwards found a convenient reason for returning to the flesh-pots of Egypt. Withal he became an expert printer, and loved the business even in his old age.

The boy composed two ballads, one on the capture of Blackbeard, the pirate, and his brother sent him out to sell them on the streets. Their sale was prodigious, and he began to think himself a poet; but the criticism of his father, who declared that rhymers were generally beggars, chilled his enthusiasm. He turned his attention to prose, which was of great use to him in after life, and formed his style on the essays of the *Spectator*, after a method of his own. He made copious notes of the sentiments in a paper, and expanded them in his own language, enlarging his stock of words by turning the tales into verse, then back again into prose, and ordering his thoughts by jumbling the hints together and re-arranging them. Thus he acquired that clear and simple style, occasionally rising into eloquence, which he employed so effectively in persuading others, and furthering both his own and the public business.

His brother started a newspaper, the *New England Courant*, which Benjamin printed and delivered. Some articles which he wrote in a feigned hand and slipped under the door of the printing-house were accepted by the editor, and the boy was flattered by the guesses of people as to their authorship. Some time after an article in the journal offended the authorities, and his brother was ordered to discontinue the paper. He, however, published it in the name of Benjamin, and cancelled his old indenture with the boy, to deceive the authorities, but got him to sign a new one for the remainder of his time. The two brothers were not agreeing well. Ben was inclined to be saucy, and the elder was passionate. So at length they quarrelled, and the boy, while smarting under the blows he had received, threw up his engagement. His brother prevented his getting work in the other printing-houses of the town, and his father siding against him, the lad took flight in a sloop bound for New York, after selling his books to raise the wind. Failing to get a job there, and having lost his desire for the sea, he removed to Philadelphia, where he had a prospect of employment. After a perilous passage in small boats, the runaway landed early on a Sunday morning in the Quaker city, which he was to render illustrious. Dirty, and in his working clothes, his pockets crammed with shirts and stockings, a roll of bread under either arm, and munching another for his breakfast, he wandered about the empty streets, not knowing what to do with himself. A girl, standing at her father's door, was highly diverted at the ridiculous figure. She was a Miss Deborah Read, and his future wife. At length he drifted into the Quakers' meeting-house, where, tired and weary, he fell sound asleep.

In Philadelphia he got work from a printer named

Keimer, who found him a lodging at Mr. Read's, and he was now very comfortable. He attracted the notice of Sir William Keith, the governor, a man who was anxious to please everybody, and promised more than he could perform. Sir William proposed that he should start in business, and gave him a letter to take to his father in Boston. Franklin went, and was reconciled to his parents; but his father declined to advance the money, on the plea that he was yet too young to begin for himself. Keith then suggested that he should go to England in the annual ship and procure the necessary plant, promising at the same time to furnish him with letters of credit. Franklin thereupon plighted his troth with Miss Read, and joined the Annis with his acquaintance Ralph, who was going to London to be a poet. But the expected letters never came, and the vessel sailed.

Franklin arrived in London on December 24th, 1724, and on finding out the governor's perfidy was advised by Mr. Denham, a Quaker merchant and fellow-passenger, to look for work at his trade. Ralph and he took lodgings in Little Britain, and Franklin obtained a berth at Palmer's printing-house, in Bartholomew Close, where he continued for nearly a year. He then shifted to Watts's, at Lincoln's Inn Fields, and removed his lodging to Duke Street. He worked hard at his business, pleasing the master by his diligence, and influencing the men by his temperate habits. He spent little on himself, except in seeing plays and buying books. But Ralph, his scape-grace friend, had eaten a large hole into his earnings. He had increased his knowledge, however, and met some interesting people, among them Dr. Mandeville, author of *The Fable of the Bees*, and Sir Hans Sloane, the antiquary. Once he swam from Chelsea to Blackfriars, and Sir William Wyndham, hearing of it, asked him to teach the art to his boys. But Franklin, tired of London, and longing to see Pennsylvania again, had accepted the offer of a clerkship from Mr. Denham.

He arrived in Philadelphia on October 11th, 1726. The following spring, when he was twenty-one, he took seriously ill of pleurisy, but recovered; a little to his regret, as he would have to die all over again. Mr. Denham passed away about this time, throwing him again upon the world. In default of a clerkship, he accepted an offer of Keimer, and returned to his old employment. Not only did he manage the works and instruct the apprentices, but he cast new type, engraved upon occasion, and made the ink.

Keimer grew more independent of his services, as the apprentices learnt the business, and once they quarrelled; but Franklin was persuaded to make it up by an apprentice named Meredith, who proposed to find the money to start in partnership with Franklin when his time was up. This was ultimately done, and the new firm prospered.

The projecting spirit of Franklin had organized a mutual improvement club, called the Junto, where points of morals, politics, and natural philosophy were discussed. It improved his powers of public speaking and of conversing, while the connection assisted him in business. He intended to begin a newspaper, but Keimer heard of it, and forestalled him. However, the enterprise failed, and Keimer sold it to Franklin, who thus became editor and publisher of the *Pennsylvania Gazette*. He had now a good field for his pen, and his articles on public matters soon attracted attention. His position likewise improved, for the leading men, if only from self-interest, cultivated his
tance. He had espoused the cause of the
against the governor, and in time procured

the printing for the Assembly. His partner, Meredith, lost character by his low habits, and eventually, in 1730, withdrew from the firm, leaving it solely in the hands of Franklin.

To gain the good opinion of his townsmen, he wasted no time in taverns or at idle games, but amused himself with reading. He dressed plainly, and, to show that he was not above his business, would sometimes wheel his paper in a barrow through the streets. He lived as plainly, and for a long time breakfasted on milk and bread, which he ate out of an earthenware porringer with a pewter spoon. Later on his wife substituted a china bowl and a spoon of silver, which was the first appearance of luxury in his house. As a boy his father had often repeated to him the proverb of Solomon, 'Seest thou a man diligent in his calling, he shall stand before kings;' and Franklin, himself a shining instance, did not forget it. His industry was such that Dr. Baird, a Scotchman, asserted he had never seen the like. 'I see him still at work,' said he, 'when I go home from the club, and he is at work again before his neighbours are out of bed.'

The debts he had incurred in buying out Meredith were gradually paid off, and he began to think of marriage. While in England he had broken his engagement to Miss Read, and she had married a worthless potter, who abandoned her, and was believed to be dead. Accordingly, when another match which was proposed for him fell through, he returned to his old love, endeavouring to correct the *erratum* of his former inconstancy, and they were married on September 1st, 1730. She proved a cheerful friend, with habits of thrifty management, and was not ashamed to help him in his business. Two of their children grew up to maturity. The son became a Royalist during the rebellion, and was estranged from his father. The daughter eventually married a Mr. Richard Bache; and continued her father's line.

Franklin was trained as a Presbyterian, but freed himself from the narrower tenets of the sect, and growing dissatisfied with doctrinal sermons, when he wished for moral teaching, he seldom went to church, although he saw the propriety of it. But he was never without religious principles, and had composed a liturgy for his own use. He drew up the following creed, containing, as he believed, the essentials of every known religion: 'That there is one God, who made all things. That He governs the world by His providence. That He ought to be worshipped by adoration, prayer, and thanksgiving. But that the most acceptable service to God is doing good to man. That the soul is immortal. And that God will certainly reward virtue and punish vice, either here or hereafter.'

Assured that vice was not a profitable investment, Franklin resolved to live without committing a fault at any time. But he soon found that he had undertaken a more difficult task than he had imagined. While guarding against one error he found himself running into another. At length he concluded that the mere conviction of virtue being his true interest is not sufficient to preserve a man from slipping, and that evil habits must be rooted out, and good ones cultivated in their stead, before he can safely rely upon the rectitude of his conduct. He therefore prepared a catalogue of the virtues which he proposed to foster seriatim. It ran:—

1. **Temperance.—Eat not to dulness; drink not to elevation.**
2. **Silence.—Speak not but what may benefit others or yourself; avoid trifling conversation.**

3. **ORDER.**—Let all your things have their places; let each part of your business have its time.
4. **RESOLUTION.**—Resolve to perform what you ought; perform without fail what you resolve.
5. **FRUGALITY.**—Make no expense but to do good to others or yourself; that is, waste nothing.
6. **INDUSTRY.**—Lose no time; be always employed in something useful; cut off all unnecessary actions.
7. **SINCERITY.**—Use no hurtful deceit; think innocently and justly; and if you speak, speak accordingly.
8. **JUSTICE.**—Wrong none by doing injuries, or omitting the benefits that are your duty.
9. **MODERATION.**—Avoid extremes; forbear resenting injuries so much as you think they deserve.
10. **CLEANLINESS.**—Tolerate no uncleanness in body, clothes or habitation.
11. **TRANQUILITY.**—Be not disturbed at trifles, or at accidents common or unavoidable.
12. **CHASTITY.**
13. **HUMILITY.**—Imitate Jesus and Socrates.

These he entered in pages ruled for the days of the week, and taking one virtue at a time, ticked off his lapses day by day. This moral day-book had for one of its mottoes the words of Solomon:—

> 'Length of days is in her right hand, and in her left riches and honour; her ways are ways of pleasantness, and all her paths are peace.'

The following prayer, which was prefixed to it, is also characteristic of the man:—

> 'O powerful Goodness! bountiful Father! merciful Guide! Increase in me that wisdom which discovers my truest interest. Strengthen my resolution to perform what that wisdom dictates. Accept my kind offices to Thy other children, as the only return in my power for Thy continual favours to me.'

Franklin carried this book always with him, and kept up the practice for many years, until the claims of public business interfered with it. ORDER gave him the most trouble to acquire, and pride was very difficult to subdue, for, as he observes, a man is even proud of his humility. He failed, indeed, to arrive at moral perfection, but he attributed to the attempt the honour and happiness of his life.

His designs for a book on the art of virtue, and for an international society of virtuous men, were never carried out; but *Poor Richard's Almanac*, with its collection of wise saws, had a wide circulation. In his newspaper he often inserted moral essays, and he kept its pages clear of all libellous and abusive matter.

In 1733 he began to study languages, working through French, Italian, and Spanish back to Latin, a method which he recommends in preference to starting with the classic tongues. About this time too he effected a reconciliation with his brother James, who was now in failing health, and made amends for breaking his indentures by assuming the care of his nephew.

In 1736 he was appointed Clerk of the General Assembly, his first official employment; and it is characteristic of Franklin that to gain the goodwill of a new member who had opposed his election, he borrowed a book from him, in the belief that a person who has once done you a kindness will be more ready to do you another, than he whom you yourself have obliged. The following year he was appointed deputy-postmaster at Philadelphia, and began to turn his thoughts to public affairs, confining himself to small matters. He reformed the city watch, and established a fire-brigade. In 1744 he founded a philosophical society, which is now the Franklin Institute or American Academy of Sciences; and five years later established an academy, which grew into the University of Philadelphia. When the plan originated with himself he prudently kept in the background, attributing it to some 'public-spirited gentleman,' and thus avoiding envy, the more readily secured assistance. He also lent a helping hand in the philanthropic schemes of others.

On war breaking out between France and Great

Britain, the peaceful Quakers, being a majority in the Assembly, refused to pass a bill to raise a militia for the defence of the town. Franklin met the difficulty by organising a force of volunteers. A battery was built, and he, with some others, was deputed to borrow the needed cannon from Governor Clinton of New York. The governor peremptorily refused them; but in dining with his council, after a glass or two of generous Madeira, he softened sufficiently to promise them six pieces. A few more bumpers brought the number up to ten, and before the feast was over he had granted eighteen guns.

During these martial times the Quakers often found it difficult to appease their consciences and vote supplies for military purposes. At last their method was to provide the funds 'for the king's use,' and inquire no further. This did not always serve, however, for on one occasion the government of New England sent them an urgent requisition for money to buy gunpowder. The wily Friends pointed out that 'powder' was an ingredient of war, but at the same time granted the required aid 'to purchase bread, flour, wheat, or *other grain*.'

In 1742 Franklin invented an open stove, which was much used in America, and pirated in England. He declined to patent it, thinking that we should welcome the opportunity of making some return for the benefits we derive from the inventions of others. Four years later, being in Boston, he met a Dr. Spence from Scotland, who surprised and delighted him with some experiments on electricity, a study quite new to him. On his return to Philadelphia the members of the library there received a glass tube for electrical experiment from Mr. Peter Collinson, a Fellow of the Royal Society, and Franklin began his researches by repeating the experiments of Dr. Spence and devising others. He sent the results to Mr. Collinson, who read his letters to the Royal Society, but they were not considered worthy of a place in the *Transactions;* and his paper on the identity of lightning and the electric spark, communicated by Mr. Mitchel, was even greeted with laughter. They were published, however, by Mr. Cave, a bookseller, under the title of *New Experiments and Observations on Electricity made at Philadelphia*, and favourably received in France, where the illustrious Buffon had them translated, and King Louis XV. witnessed a repetition of the experiments at St. Germains.

Gilbert's discoveries had given a new life to the study of electricity and magnetism. Prior to the time of Franklin, Otto von Guericke, burgomaster of Magdeburg, had invented an electrical machine, in which electricity was developed by rubbing a ball of sulphur between the hands. He discovered that sound and light were produced in the act, and compared the luminosity to that seen on breaking a lump of loaf sugar in the dark. Sir Isaac Newton employed glass in place of the sulphur, and suggested the use of friction rubbers. In short, the electric machine had been greatly improved, and sparks several inches in length could be obtained from it. The likeness of these to a flash of lightning had not been unobserved. Dr. Wall compared the crackling of the spark to thunder, and Stephen Gray, a 'Brother' of the Charterhouse, had recognised on his death-bed that a means would yet be found of collecting larger quantities of the electric fire, which, from his experiments, seemed to be of the 'same nature as thunder and lightning.'[1]

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[1] The Abbé Nollet, in his *Leçons de Physique Experimentale*, published in 1746, refers to thunder as being in the hands of *Nature what electricity* is in the hands of the chemist.

His remarkable prediction was soon fulfilled by the discovery of the Leyden phial, or electric bottle for collecting electricity. In 1745–6 Professor Muschenbroeck of Leyden University attempted to confine a charge of electricity in water by enclosing it in a bottle of glass, which was known to be an insulator. Cuneus, a pupil of his, and burgess of the town, repeated this experiment, but held the bottle in his right hand while the water was connected by a chain or wire to the prime conductor of an electrical machine. After charging the water Cuneus innocently put out his left hand to withdraw the wire, and received a violent shock which made him drop the vessel on the floor.

Muschenbroeck, on hearing of the novel effect, was himself anxious to try it. He underwent a still more lively convulsion. It was two days before he recovered from his fright, and he declared in a letter to Réaumur that he would not submit himself to a second shock for the whole kingdom of France. Others were not so timorous, and Boze of Wittemburg professed his readiness to be killed by it, for the glory of a memoir to the French Academy of Sciences.[1]

Gray had discovered that some bodies conduct electricity better than others; hemp, for example, better than silk, and metal better than wood or stone. The former he called *electrics*, the latter *non-electrics*; but they are now distinguished as *conductors* and *insulators*. He had even transmitted a charge of electricity along a considerable length of ordinary string suspended by loops of silk.[2] Various effects of electricity had also been discovered. Gordon of Erfurt,

[1] Von Kleist, a Dean of Kamin Cathedral, in Pomerania, is also said to have discovered the Leyden jar.

[2] Gray's memory might well be perpetuated by a mural tablet in the cloister of the Charterhouse, which bears the names of Thackeray, Leech, and other distinguished inmates of the house.

a Scotch Benedictine monk, had ignited spirits, killed small birds, and hastened the evaporation of water by the spark; while Mowbray of Edinburgh had fostered the growth of myrtle plants by electrifying them. It was beginning to be seen that there was a great future before the new agent, which, however, was still of no practical use, and little more than a plaything of the curious.

As to its nature, a likely theory had been advanced by M. Dufay, a Member of the French Academy of Sciences. He asserted that glass and resin produced electricity of opposite kinds, which he termed *vitreous* and *resinous*; and he showed that while they attracted one another, they repelled electricity of their own sort. Franklin was the first to refute this promising hypothesis.

In his opening letter to Collinson, dated March 28th, 1747, he remarks that he had never before engaged in a study which so totally engrossed his attention to the exclusion of other business. His first communication to the Royal Society deals with his observations on the aptness of points to discharge electricity, and expounds his belief that there are not two kinds of electricity, as Dufay supposed, but that the *vitreous* is an excess or *positive* quantity, and the *resinous* a deficiency or *negative* quantity of the same fluid. The Abbé Nollet, a friend of Dufay, attacked this new hypothesis; but Franklin left his experiments to defend themselves, and *Franklinism* ultimately triumphed.

He also explained the Leyden jar, which was a great mystery to the scientific world. Franklin showed that when the inner conductor or coating, which corresponded to the water in the original experiment of Cuneus, was positively charged, the outer coating, represented by the hand of Cuneus, became negatively charged, and that when these were joined together by a conductor, as was the case when Cuneus tried to take away the chain, the positive rushes to the negative, and thus the unsuspecting Cuneus received a shock through his body.

One of Franklin's letters to Collinson reads with a curious interest to-day.

> 'Chagrined a little that we have hitherto been able to produce nothing in the way of use to mankind, and the hot weather coming on, when electrical experiments are not so agreeable, it is proposed to put an end to them for the season, somewhat humorously, in a party of pleasure on the banks of the Schuylkill. Spirits at the same time are to be fired by sparks sent from side to side through the river without any other conductor than the water, an experiment which we sometime since performed to the amazement of many. A turkey is to be killed for our dinner by the *electrical shock*, and roasted by the *electrical jack*, before a fire kindled by the *electrical bottle*, when the healths of all the famous electricians in England, Holland, France, and Germany are to be drunk in *electrified bumpers*, under the discharge of guns from the *electric battery*.'[1]

In sending a spark across the Schuylkill river, the circuit was completed by a wire stretched over the water at the ferry. One end of it was connected to the outer coating of a Leyden jar, the other to a metal spoon containing a little spirits. The inner coating of the jar was connected through a post with the water, and the spark was directed to the spirits by a metal point communicating with the water. Dr. Watson, in London, had also administered 'shocks' to people across the Thames at old Westminster Bridge by a similar arrangement. But neither he nor the ingenious Franklin, whose mind was bent on a practical application, discerned in this experiment the germ of an electric telegraph. How true it is that even the keenest intellect can see but a little way along the paths of science! It was reserved for one 'C. M.,' believed to be Charles Morrison, an obscure surgeon of Renfrew, to publish the first plan for a practical telegraph, based on the transmission of electricity along insulated wires, and the attraction of light indices, corresponding to the letters of the alphabet at the distant end. 'C. M.'s' telegraph has the merit of being practical, but though it was clearly explained in the *Scots Magazine* for February 17th, 1753, it was never carried out. A similar device was tried, however, later on.[1]

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[1] The electrified bumper was a glass of wine electrified; the bottle a Leyden jar, the jack and battery devices of Franklin. All these feats can now be done on a practical scale, and modern convivial societies of electricians might borrow a hint from their American prototype, which seems to have been instituted by Franklin.

Franklin had sense enough to believe in the future of the new science. 'Of what use are these experiments?' inquired an onlooker one day. 'Of what use is an infant?' replied Franklin; and his confidence was soon to be justified by the invention of the lightning rod.

In 1749, he drew attention to the sameness of the lightning flash and the electric spark, that both pursue a crooked path and dart upon high points, both blind and kill animals, fuse metals, and ignite combustibles, magnetise needles, and reverse the poles of the compass. To prove their identity, he proposed to erect an iron rod upon some tower or eminence, with its point in the sky, and its foot insulated on a cake of resin, and he expected to obtain sparks from it when a thundercloud passed overhead. He even suggested the protection of buildings by metal rods terminating in the ground, so as to ease the cloud by a slow discharge, or carry off a sudden flash.

In the summer of 1752, Franklin attempted his experiment of drawing down fire from the clouds. He had waited for the completion of a spire, in course of building at Philadelphia, but, losing patience, he constructed a kite by stretching a silk handkerchief over a cedar frame. A pointed wire projected from the upright stick, and a proper tail was added. To the end of the string he attached a length of silk ribbon for holding it by, and a metal key from which to draw the sparks. One day in June a thundercloud was seen approaching, and Franklin started out to test the truth of his opinions, taking his son with him, but concealing his intentions from others, in case of failure. On reaching the common he flew the kite, and stationing himself under a shed out of the rain, awaited the result. The nimbus passed slowly over, but on presenting his knuckle to the key he could elicit no sparks. At length he began to think of giving up in despair, when suddenly he observed the floss on the twine to bristle out as if it were electrified. He tried, and found it was attracted to his finger; the key now yielded a spark, and when the rain had 1752 wetted the string, the supply was so copious that he charged a Leyden jar. Spirits were afterwards ignited × from it, and many other crucial experiments performed.

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[1] **It is said that 'C. M.' was thought a kind of wizard, that he *was connected* with the tobacco trade, and died in Virginia.**

Some weeks before this, Buffon, D'Alibard, and De Lor, in following the other plan of Franklin, had erected three rods at different points. That of D'Alibard was planted in a garden at Marly-la-Ville, and was the first to give a definite result. It had been left in charge of an old dragoon, named Coffier, who; on the afternoon of May 10th, about twenty minutes past two, applied his wire to the rod after a smart thunderclap and drew a tiny spark. Elated with his success, Coffier sent for the prior, M. Raulet, and as the good man hastened to obey the summons, the villagers hurried after, and the rumour spread that Coffier was killed by lightning. On the 18th of the same month, De Lor's rod, on the Estrapade in Paris, was likewise successful, and the experiment was confirmed by others, such as Beccaria in Turin, Canton in London, and Professor Richman of St. Petersburg. Richman erected an iron rod on his own house, having its point projecting above the roof and its base connected to a Leyden jar, and an 'electrical gnomon,' or simple electrometer, which indicated the strength of the charge by a miniature plummet. In the autumn of 1752, he obtained some sparks from the rod, and the following summer received a smart shock. Later in the year, on the 6th of August, on hearing a rumble of distant thunder while present at a meeting of the Academy of Sciences, he left the chamber and hurried home, taking with him M. Sokolow, an engineer, to sketch whatever might occur. On their arrival, the 'gnomon' exhibited signs of electrical disturbance, the plummet having risen four degrees from the vertical. If it should reach to forty-five degrees, observed Richman to his friend, the consequences might be serious. While he was yet speaking, a tremendous crash of thunder shook the city to its foundations. Richman bent forward to read the gnomon, and suddenly, with a loud report, a ball of bluish fire shot from the rod and struck him on the head. Richman fell back on a chest against the wall, and Sokolow, dazed by the shock, and suffocated by the fumes, his clothes on fire with the red-hot sparks, rushed wildly out of the house, calling aloud to the people. In the meantime, Madame Richman, alarmed at the noise, ran into the laboratory, and found her husband sitting bolt upright against the wall. It was the attitude of life; but the glassy eye, the blood oozing from his mouth, told that he was dead. A doctor was instantly sent for, and one of his veins was opened, but the blood would not flow, nor did most violent friction restore his vitality. His showed the usual marks of death by lightning;

red and blue spots were found on the skin of the back and left side, the brain was normal, but the lungs and other internal organs were injured. His left shoe was burst open, and there was a blue mark on the foot itself beside the hole, thus showing how the discharge had travelled. The apartment was filled with 'sulphurous' fumes, the door was rent, the ashes of the hearth were scattered, the Leyden jar was broken, and the clock, like its master, had stood still.

Franklin's experiment founded the study of atmospheric electricity, and led to the protection of houses by the lightning rod, a first application of the science which must have greatly pleased him. The Royal Society now redeemed its former slight, by creating him a Fellow, and conferring on him its highest honour, the Copley Medal. Louis the Fifteenth sent him, through the Royal Society, his express congratulations.

The discovery had, moreover, struck the popular imagination. It was illustrated by every flash of lightning, and bruited by every peal of thunder. The homely Franklin was regarded as a new Prometheus, who had despoiled Jupiter of his thunderbolt, and tamed that blighting and capricious fire which until then had kept the 'world in awe.'

A new light was cast upon old mysteries. St. Elmo's fire, the dread of superstitious mariners, which Ariel employed in the *Tempest*, was now seen to be a discharge of electricity from the pointed masts and slender rigging of the ship. The flames which tipped the javelins of the Roman legion after the storm in Africa, as related by Cæsar, were, doubtless, a phenomenon of the same kind.

It was also remembered that a sentinel at the Castle of Duino in the Frioul used to draw sparks with his halberd from an iron point on the ramparts, ere he would ring the alarm bell to warn the peasants that a storm was coming.[1] The incident shows us how an ignorant and uninquiring mind may overlook a great discovery; and in this respect it throws into stronger relief the discovery of Franklin. To regard it as a forestallation would be almost as ridiculous as to suppose that Ajax, when he defied the lightning with his uplifted sword, knew that the bronze was a conductor. Some curious contrivances were suggested for ensuring safety in a thunderstorm; but, perhaps, the most amusing was a cap with a long metal chain which trailed upon the ground, and thus protected the wearer.

Franklin's fame, which began in Europe, soon reached him in Philadelphia, where he was now the most distinguished citizen. Having retired from active business, with a moderate fortune, accumulated by his own diligence and sagacity, he intended to devote his well-earned leisure to the pursuit of science. It was evidently an occupation which engaged his whole heart, and he was admirably fitted for it. He possessed a practical imagination, a rational judgment, and a quick perception, all of which had been cultivated during his past career by an active intercourse with the world. Moreover, he was a man of great perseverance and simple habits, with a natural turn for handicraft. But the public claimed him for its own, and the benevolent Franklin, flattered no doubt by his own success and their approval, but still more pleased to have the opportunity of doing good, accepted their appointments. Among other things, he was elected to the Assembly, resigning the clerkship to his son, and soon afterwards was made a postmaster-general. He was instrumental in founding a hospital in Philadelphia, and in getting the streets properly paved and lighted; for, as he remarks in his delightful *Autobiography*, 'Human felicity is produced not so much by great pieces of good fortune that seldom happen, as by little advantages that occur every day.'

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[1] Arago, *Éloges Historiques*.

When the war broke out with France, in 1754, he attended a Congress at Albany, to hold a pow-wow with the chiefs of the Six Nations; and here, like Thales at the Panionium, he proposed the confederation of the colonies for mutual defence. Had this plan been adopted, it might have prevented the revolution, and the final severance of the colonies from Great Britain; but it was ultimately rejected by the home government. He catered for General Braddock's army, and, after its defeat, conducted a winter expedition into the backwoods to build stockades for the protection of the settlers from the Indians on the north-west frontier. The chaplain of the force complained to him that the men would not attend prayers. Franklin hinted that if he would serve out the rum and then hold the service he would have a good congregation. The plan was a great success.

On his return home he was appointed colonel of the militia, but did not seem to hanker for a military life. A quarrel had long been brewing between the popular Assembly and the 'Proprietaries,' as the sons of William Penn, who founded the colony, were termed. When the Assembly voted money for defensive purposes, the Proprietaries considered themselves exempt from the tax, and unless this privilege were granted, they instructed their deputy-governors to veto the bills. At length the Assembly resolved to petition King George on the matter, and Franklin was sent to England on the mission. After nearly running on the Scilly rocks, the vessel anchored in

Falmouth Harbour on the morning of July 17th. 1757. 'The bells ringing for church,' he wrote to his wife, 'we went thither immediately, and, with hearts full of gratitude, returned sincere thanks to God for the mercies we had received. Were I a Roman Catholic, perhaps I should on this occasion vow to build a chapel to some saint; but as I am not, if I were to vow at all, it should be to build a lighthouse.'

The press of London sided with the Proprietaries, and the ministers of the crown were busy with the Seven Years' War in Germany; but, after three years, Franklin gained his point, and the Proprietaries were subjected to taxation. This result was partly brought about by a pamphlet, supposed to be written by his old friend Ralph, who after being satirised as a poet in the *Dunciad* was now a political writer of some note. Franklin is said to have suggested the conquest of Canada to the ministry, who initiated the expedition of General Wolfe. He recognised the importance of that country, and after the revolution was equally anxious to secure it to the United States. During the summer months he travelled in Great Britain or abroad, and in this way visited the seat of his ancestors at Ecton, and assisted some of his poor relatives. In 1760 he spent a long holiday in Scotland, as the guest of Lord Kames, meeting Hume, Robertson, and other eminent men. In a letter to Kames he says of this visit: 'I must say I think the time we spent there was six weeks of the *densest* happiness I have met with in any part of my life;' and he goes on to declare that, but for his connections elsewhere, he would choose to spend the rest of his days in Scotland. Edinburgh and St. Andrews granted him the freedom of the city, and their universities the degree of LL.D., a distinction which he also received from Oxford. The following year he visited Holland and Flanders, returning in time for the coronation of George III. In London he stayed with Mr. Stevenson, at the house in Craven Street now marked with a tablet. On one occasion he was laid up with a fever for eight weeks; and though he saw a great deal of the best society, he remarks, in a letter to his wife, that the thoughts of home and his family often made him sigh in the most cheerful company. He returned to Philadelphia in November 1762, where he received the thanks of the Assembly and a grant of £3000. The following year he mollified the insurrection known as the Paxton Murders, in which a band of armed white men brutally murdered a clan of friendly Indians, under their venerable chief, who had been present at the second council of the redmen with William Penn.

The feuds between the Proprietaries and the popular Assembly, of which Franklin was now the Speaker, were not healed, and Franklin was again sent to London, in 1764, to petition the king to assume the sole government of the province. He also carried a remonstrance against the obnoxious Stamp Act, the 'mother of mischief,' as he called it; for the colonists were indignant at being taxed by the British Parliament, in which they had no voice. On February 3rd, 1766, Franklin appeared at the bar of the House of Commons to plead the impolicy of the Act, and succeeded in obtaining its repeal.

During this visit to Europe he travelled again in Scotland, and was present at the opening of the Irish Parliament in 1771. In 1776 he journeyed with his friend Sir John Pringle to Holland, Germany, and Paris, where he was presented to the king and the royal family.

He still occupied himself with science at odd times, and in 1772 was member of a committee of the Royal Society to consider the best form of lightning rod for the powder magazines of Purfleet. A controversy arose as to whether the rods should terminate in balls or points. The king's attention was called to the matter. George III. inquired what was the view of Franklin; and on being told that his political opponent was in favour of 'points,' he declared his preference for 'balls.' Franklin also wrote on the analogy of electricity and magnetism, and confirmed the discovery of pyro-electricity by Aepinus. He performed a number of experiments on the calming of waves by shedding oil upon the water; and during his voyages across the Atlantic he studied the temperature of the Gulf Stream and its probable influence on the weather. He also invented the *armonica*, an arrangement of the musical glasses which became the vogue. From early life he had been partial to music, and his remarks on the melody of Scottish tunes are certainly ingenious. He points out that their intervals are generally thirds, fifths, and octaves, so that every note is in harmony with the impression left in the ear by the preceding note. To the scientific spirit all things are food for thought, nothing is too mean to study, and even a grain of sand has its history. Franklin, in his leisure moments, investigated a variety of matters, and often with a practical result. 'A singular felicity guided all his researches,' observes Sir Humphry Davy, 'and by very small means he established very grand truths. . . . He has in no instance exhibited that false dignity by which Philosophy is kept aloof from common applications; he has sought rather to make her a useful inmate and servant in the common habitations of men, than preserve her merely as an object of admiration in temples and palaces.'

The repeal of the Stamp Act appeased the colonists for a time, but the principle of taxation by the Imperial Parliament was not surrendered, and their discontent broke out again. Franklin, as agent for several colonies, tried every means of averting the revolution which was now imminent. In 1772 a number of letters written by the governors of Massachusetts in favour of coercive measures against the people of that province were placed by some unknown person in his hands. He deemed it his duty to communicate them to the Massachusetts Assembly, where they were received with the greatest indignation, and a petition drawn up asking the king to remove the offending officers. The case was tried before the Lords of the Privy Council on January 29th, 1774. Franklin appeared to present the petition, and its rejection was moved by Sir William Wedderburn, the Solicitor-General. It might have been supposed that the renowned philosopher, thrice venerable by his age, his aspect, and his genius, would have met with some respect. But the astute lawyer, conscious perhaps of the weakness of his case, directed a virulent attack against the personal character of Franklin, which drew repeated bursts of laughter and applause from the assembled noblemen. The old man bore this despicable and unprovoked assault with a dignified equanimity, and made no reply. The petition was rejected, and on the following day Franklin was dismissed from the office of postmaster-general. He did not resent the insult; but it is said that he never wore the same suit of clothes until the day he signed the treaty with France as the plenipotentiary of the United States.

Other attempts at reconciliation proving futile, he left for home, where he arrived on May 5th, 1775. His faithful wife had died during his absence, his son had joined the Royalists, and only his daughter remained to cheer his fireside. Instead of attaining the rest and tranquility to which his age and services entitled him, Franklin was entering on his busiest period. The threatened storm had burst, and the colonies were in a fever of preparation for the war with Britain. He was an active member of three public bodies—the Assembly of Pennsylvania, the Congress of the Colonies, and the Committee of Public Safety, besides serving in other capacities. He drafted a plan of confederation, which was afterwards useful in framing the constitution of the United States. He made a journey through the backwoods to Montreal, in order to secure the co-operation of the Canadians, and seriously injured his health by the exposure, while failing of his object. He assisted in drafting the Declaration of Independence, and was one of those who signed it on the famous 4th of July. 'We must be unanimous,' said Hancock on this occasion; 'there must be no pulling in different ways; we must all hang together.' 'Yes,' replied Franklin; 'we must indeed all hang together, or most assuredly we shall all hang separately.'

To gain the assistance of France in the struggle for independence he was despatched to Paris, where he became the hero of the day and the incarnation of the new principles of liberty, equality, and fraternity. 'His virtues and renown,' says M. Lacretelle, 'negotiated for him': and the defeat of Burgoyne removed the last hesitation of the French Government. A treaty of alliance was concluded on the 6th of February, 1778, and in a few weeks Franklin was received at court in the character of American ambassador. His plain but venerable aspect marked him out among the laced and powdered courtiers of Versailles. The sturdy figure, clad in a snuff-coloured coat and knee-breeches, was that of a country farmer; but the brown hair silvered with time and flowing unconfined upon his shoulders, the bright but tranquil eye, the cleanshaven face and snowy neckcloth, added something of the cleric to his appearance. The people crowded to see him as he left the palace, and hailed him with enthusiastic cheers.

He mingled with the best society of Paris, and was introduced to Voltaire during his last visit to the capital. They conversed in English, and when Madame Denis proposed that they should use French and give others the benefit of their sentiments, Voltaire replied, 'Excuse me, madame, but I have the vanity to show that I am not unacquainted with the language of a Franklin.'

His time was occupied with many affairs, both official and unofficial. He assisted in planning a piratical expedition against England, under the notorious Paul Jones; for, having tried his best to prevent the war, he was resolved to do his utmost to win the victory. But he instructed American cruisers not to molest the ships of Captain Cook, or those of the Moravian missionaries in Labrador. He was a regular attendant at the French Academy of Sciences, of which he was a member, and read a paper to it on the aurora borealis, besides taking part in a commission to investigate the experiments of Mesmer. From the terrace of his house at Passy he witnessed the first ascent of the Montgolfier baloon, with Pilâtre de Rosier and the Marquis d'Arlandes in the car, on November 21st, 1783, and sent an appreciative account of it to Sir Joseph Banks.

Peace had been concluded with Great Britain on the 30th of November, 1782; but Franklin was not permitted to return home until he had negotiated other treaties, the last with Prussia, which contained a new article against privateering in time of war.

He arrived at Philadelphia, and landed at the Market Street Wharf, on which, more than sixty years before, he had jumped ashore a friendless wanderer. The whole population of the city had now assembled to welcome him with shouts of joy and affection. The bells of the steeples were rung, a military salute was fired, and the public bodies waited on him with their congratulations, as though he had been their king.

The following day he was created a member of the supreme executive council of Philadelphia, and soon afterwards the President of the State of Pennsylvania. Two years later, when eighty-two years of age, he was appointed a delegate to the convention for drawing up the federal constitution of the United States, and in memorable words proposed the opening of the house with daily prayers. 'I have lived, sir,' said he, 'a long time, and the longer I live the more convincing proofs I see of this truth, *that* GOD *governs in the affairs of men.* And if a sparrow cannot fall to the ground without His notice, is it probable that an empire can rise without His aid?' The motion was not adopted, as the convention, with a few exceptions, considered 'prayers unnecessary.'

At length, after more than fifty years in the service of his country, he could enjoy the gloaming of his life in peace and quiet. 'I am now got into my niche,' he wrote, 'after being kept out of it twenty-four years by foreign employments.' The house, built by himself, stood apart from the street, and here, in the family of his daughter, the venerable doctor might be seen at work among his books and curiosities, or sitting under a mulberry tree in the garden, with his grandchildren playing beside him on the grass.

It was a fitting close to his long and honourable life; but, alas for human felicity! his last years were not permitted to glide away untried. He suffered from stone, and was seldom free from acute pain. 'For my own personal ease,' he wrote to President Washington, in 1789, 'I should have died two years ago; but though those years have been spent in excruciating pain, I am pleased that I have lived them, since they have brought me to see our present situation.'

Despite these sufferings, his mental faculties continued unimpaired to the last. In the intervals of relief, he wrote papers and devised philanthropic schemes. He was much interested in the improvement of public prisons and the condition of the negro slaves, his last public act being to sign a memorial on their behalf to Congress, as President of the Abolition Society of Pennsylvania, and his last paper, written twenty-four days before he died, a parody of a speech which had been delivered in defence of slavery.

On the 1st of April, 1790, he complained of fever and a pain in the breast. On the 17th he quietly 190 expired about eleven o'clock at night. A few days before this, he rose up from his last bed, and begged that it might be made up, so that he could 'die in a decent manner.' His daughter expressed a hope that he would recover and live many years. 'I hope not,' replied Franklin. On being urged to change his position, that he might breathe easily, he said, 'A dying man can do nothing easy.'

The funeral took place on the 21st of April, and was attended by an immense number of people, including a procession of students and members of public bodies. The bells were muffled, the flags of the shipping flew half-mast high, and a salvo of artillery announced the committal of his body to the earth. He was laid beside his wife in the cemetery of Christ

Church, and the place marked by a simple slab of marble. The National Congress went into mourning, as also did the French Assembly, on the motion of Mirabeau, seconded by Lafayette.

Franklin was a strong, well-built man, of five feet nine or ten inches in height. His features, without being fine, were open and agreeable; his grey eyes placid and reflective, but not dull; his mouth was large, but firm, and his jowl a trifle heavy. His complexion was fair, but in later life his hair became white, and hung in long locks from his bald crown upon his shoulders. His manner was easy, affable, and at times vivacious. His talk was interesting, from his wide knowledge of men and things, as well as the anecdotal turn of his mind. In a mixed society or alone with strangers he was apt to be reserved. In public he seldom spoke, but always briefly and to the point, enlightening his remarks with anecdote.

In making his way in life Franklin pursued his own advantage, but never at the cost of truth and honesty. Even then he was generous; and in after years his only aim was to benefit his fellow-men. Indeed, he regarded his own fortune as the means of enabling him to deal justly, and to do good to others. His success was greatly owing to the mastery he acquired over his passions and his talents. He was thus able to pursue an object steadily with all his might, and rarely failed to attain it. 'My rule,' says he, 'is to go straight forward in doing what appears to me to be right, leaving the consequences to Providence.'

He wrote a great deal, but rather for some practical object than to advance literature. The best edition of his works is that edited by Jared Sparks.

As the first American philosopher, and one of the fathers of his country, Benjamin Franklin has been honoured with a statue in his native town; but his fame rests on a broader basis, for he was a benefactor of the human race, and, to quote the epigram of an admiring Frenchman,

> 'On l'a vu desarmer les tirans et les dieux.'

CHARLES AUGUSTIN DE COULOMB.

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COULOMB has been regarded as the pioneer of experimental science in France, as William Gilbert was in England. The fame of both rests principally on their electrical and magnetic researches. Gilbert, the physician, who flourished two centuries earlier, obtained results which were chiefly qualitative. Coulomb, the mathematician and engineer, with the love of definition and the habit of measurement, inheriting the advances which had been made meanwhile, arrived at quantitative results. He gauged the forces of attraction and repulsion between electrified bodies or magnetic poles, and formulated the laws which governed them.

Charles Augustin de Coulomb was born at Angoulême, on June 14th, 1736, of a good family belonging to Montpelier, which had furnished members to the provincial parliament. He went to school at Paris, and discovering a bent for mathematics, entered the army as a military engineer. Being drafted to the island of Martinique, in the West Indies, he took part in the erection of Fort Bourbon. But the climate was then fatal; most of his comrades died of fever, and Coulomb, after a stay of three years, returned home with his health permanently injured.

His services in the colony were unrewarded, owing to a change of ministry. He was engaged on military duty at Aix, Rochelle and Cherbourg, but also employed his leisure in original work. In 1773 he gained some distinction by a paper on 'Statical Problems applied to Architecture,' which was presented to the Royal Academy of Sciences, of which he became a corresponding member. Six years later he shared with Van Swinden, the author of *Positiones Physicæ*, a prize offered by the Academy for the best mode of constructing mariners' compasses. He was now resident at Rochefort, and in its naval arsenal carried out the experiments on friction and the stiffness of ropes that were published in his memoir on the *Theory of Simple Machines*, which obtained a double prize of the Academy in 1781. This year he had the good fortune to be established in Paris, and soon improved his position. A scheme for a navigable canal was brought before the States of Brittany, and the Minister of Marine appointed Coulomb to report upon it, as commissary of the king. He condemned the plan as expensive and unprofitable; but it was supported by influential persons, who, in the tyrannous fashion of the time, procured the detention of Coulomb in the prison of the Abbaye, on the frivolous pretext that he had accepted his commission without leave from his superior, the Minister of War. Indignant at this ill-treatment, Coulomb sent in his resignation, but it was not accepted. He was liberated, and then remanded to Brittany, in order to reconsider the project. But his new examination only confirmed his former opinion, which at length began to prevail, and the States, in gratitude for his services, offered him a handsome present; but Coulomb only accepted a seconds' watch, which was afterwards useful in his experiments.

In 1784 he was made Intendant of the Waters and Fountains in France; and two years later obtained the reversion to the post of Conservator of Plans and

Reliefs. He rose to be lieutenant-colonel in the engineers, and was nominated a chevalier of St. Louis and a member of the Legion of Honour. About this time, too, he was sent into England by the Academy of Sciences, as one of a commission to study the administration of the hospitals in that country.

In 1784 he presented a paper to the Academy on the elasticity of wires under a twisting stress. While making these experiments he observed that a very feeble force was sufficient to twist a long thin wire through a large angle, and thus was led to invent his well-known torsion balance. It consists essentially of a light index or 'needle' suspended by a fine wire, and screened from currents of air by a glass cover. When the needle is deflected from its zero position through a certain angle by a disturbing force, it can be brought back to zero against the force by counter-twisting the suspension wire, and the torsion of the wire becomes a measure of the disturbing force. To this end a graduated scale is added, to indicate the turns of the counter-twist. The rate of oscillation of the needle when deflected is also a means of calculating the disturbing force.

The torsion balance has been used for many purposes, notably by Cavendish in determining the density of the earth, by comparison with that of a ball of lead. But it was never applied more successfully than by its inventor. The feeble forces of frictional electricity and magnetism awaited measurement, and Coulomb undertook the work. Gilbert had used a pivoted needle to detect these forces, but not to gauge their intensity. Coulomb's needle was much more sensitive. He constructed one in which a degree of the scale was equivalent to a force of $\frac{1}{100000}$ of a grain weight; and another in which the needle, suspended by a single fibre of silk, was deflected through a right angle by a stick of rubbed sealing-wax held at the distance of a yard.

By presenting electrified bodies to the needle, which could itself be electrified, Coulomb discovered that the force of attraction or repulsion between two quantities of electricity was directly proportional to the quantities, and inversely proportional to the square of the distance between them. That is to say, he found that the electrical forces obeyed the same law as the force of gravitation.[1] If the distance between the bodies was doubled, or trebled, or quadrupled, the force they exerted on each other was respectively a fourth, a ninth, or a sixteenth of what it had been.

Coulomb also found that electricity parts itself between a number of conductors by contact, and sheds itself over their exterior surfaces, where it resides. So that if a charged conductor were turned outside in, the charge would shift its place to keep on the exterior. Armed with a little insulated carrier of electricity, which he called a 'proof-plane,' he tested the distribution of electricity on the surfaces of conductors of different shapes, and found that the density of charge was greatest on sharp points and edges. He also showed that the loss of charge from a conductor increased with the density of the charge and the humidity of the air; discoveries which illustrated the failure of Gilbert's experiments in moist weather, and Franklin's observation that pointed conductors are the best dischargers. All these effects Coulomb explained by the tendency of electricity to repel its like.

In the same way Coulomb proved that the force of attraction or repulsion between two magnetic poles is directly proportional to the strength of the poles, or, to use a later phrase, the quantity of ideal magnetic matter in the poles, and inversely proportional to the square of the distance between them. He showed that the poles were situated near but not quite at the end of a magnet. He investigated the influence of size and shape on the directive power of magnetic needles, and showed that it was better to attach a set of parallel needles to the compass card than a single one. He devised a novel method of magnetising needles by stroking them from the middle to the ends by two magnets while supported between the poles of two other magnets; and he constructed a very powerful magnetic battery. He adopted the view that every magnet was made up of minute parts, each a tiny magnet, and he demonstrated that iron lost its magnetic virtue when raised to a temperature of 700° Centigrade, that is, when red hot.

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[1] We give the full expression of the law. Cavendish and *others also discerned it.*

These, and more discoveries of the kind, were made between the years 1785 and 1789. They paved the way for the theorems of Poisson and others; and the international congress of electricians at Paris in 1884 have signalised their value by terming the practical unit of electric quantity, a 'Coulomb.'

At the outbreak of the Revolution, in 1789, Coulomb resigned all his appointments; and, expelled from Paris by the edict which banished the aristocracy, he retired with his friend the Chevalier Borda, to a small estate near Blois. The Royal Academy of Sciences was suppressed, and his name struck out of the Commission on Weights and Measures. After a time, however, he was recalled to Paris by the revolutionary government, to assist in determining the new system of weights and measures which had been decreed. At the desire of his wife, however, he returned again to the country to devote himself to the care of his family. But, on the restoration of the Academy of

Sciences as the Institute of France, he went again to Paris, and became one of its original members. He was now appointed Inspector-General of Public Instruction, and made a tour in the provinces, where he created a favourable impression by his paternal kindness to the pupils of the schools.

In spite of his ill health, official duties, and vicissitudes of fortune, Coulomb made a considerable number of investigations, chiefly of an engineering nature. At Blois he observed that the sap of poplar trees ascended near the centre of the trunk, and was mixed with air, which could be tapped by a bore-hole. He investigated the friction of pivots; the viscosity of fluids; and the energy of men as affected by food and climate, showing that a labourer in the West Indies only did about half the work of one in France. His last researches were in magnetism. Formerly he had believed that the magnetic property was common to all bodies, in some degree; but just before his death he found reason to modify his opinion, by observing that a grain of iron could communicate a sensible magnetism to 20 lbs. of another substance. A collected edition of his various memoirs was published by the Société Française de Physique of Paris, in 1884.

Coulomb had long suffered from chronic ailments, and being attacked by a slow fever, he died at Paris on August 23rd, 1796.

He was the first to apply mathematics to the phenomena of electricity, and his experimental work was exact as it was profound. Moreover, his moral conduct was as correct as his experimental work. The affair of the canal is a sign of the integrity and independence of his public character. In private life he was an affectionate and prudent husband, happy in the society of his wife and children. His disposition was benevolent and disinterested, without weakness;

and modest, but not spiritless. Notwithstanding the irritations of ill health acting on a nervous temperament, his manners were gentle, and sometimes mildly gay. Severe with his own, he was nevertheless indulgent to the faults of others; and while his serious character inspired respect, his amiable behaviour made him popular without exciting envy. So little did he care for wealth, that he left his two sons little patrimony except the love and gratitude of his fellow men. Take him for all in all, Coulomb was an honour to his country.

ALESSANDRO VOLTA.

ALESSANDRO VOLTA.

Alessandro Volta was born at the town of Como, in Lombardy, on the 18th of February, 1745.[1] He was the son of Filippo, a poor patrician, and Maddalena dei Conti Inzaghi. The child was dull of wit, and at the age of four was still unable to speak. After that, however, his tongue came, and his intellect quickened at the same time, to the surprise and joy of his parents, who had begun to reckon him an imbecile. '*Io aveva in casa un diamante e non lo conosceva*,' said his father. 'I had a diamond in the house and did not know it.' He was put to the Jesuit school of rhetoric in Como, and soon became the leading scholar. He devoured every work he could lay his hands upon, and could remember their contents. At fifteen we find him playing the part of Uranio in a drama acted at the school. Later on, he composed a number of fluent and original verses in Latin, French, and Italian; one upon the ascent of Mont Blanc by De Saussure, and another written in Latin hexameters at the age of nineteen, on the phenomena of chemistry. The latter theme is significant of his final bent, since a youthful poet rarely, if ever, draws his inspiration from the limbeck. Indeed, he had already been in correspondence with the Abbé Nollet on a new theory of
trical attraction. But Volta never lost his taste
rature, and was an admirable judge of books.

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full name is Alessandro Giuseppe Antonio Anastasio

He finished his education at the Royal Seminary in Como, and brought himself into notice by a letter to Beccaria, which was published in 1769, under the title of *De Vi attractiva Ignis Electrici.* It shows that even at twenty-four his mind was turned to the generation of electricity by chemical action. This, and a second paper, *Novus ac Simplicissimus Electricorum Tentaminum Apparatus,* published two years later, are for the most part speculative; but there is a reference in the former to experiments he had made in getting electricity by rubbing metals together, and in the latter he describes an electric machine insulated with dried wood. Henceforth, his papers are strictly experimental. In 1774 he was appointed Rector of the Royal School in Como, where he had opportunities of research, and the following year, in a letter to Priestley, announced his discovery of the Electrophorus, to which he was led by studying the insulating property of oiled wood. His next investigations were purely chemical. In 1776 he showed that inflammable gas could be produced by decaying animal and vegetable matter, and about the same time constructed the hydrogen lamp in which a jet of the gas is ignited by the spark from an electrophorus. The following year he took a holiday in Switzerland, and at Geneva made the acquaintance of De Saussure, the historian of the Alps. At Berne he was introduced to Haller, who was then killing himself with opium; and at Ferney he had an interview with the celebrated Jean Jacques Rousseau. On his way home by the Belle-Aigue, he introduced the culture of the potato from Savoy into Lombardy, and thus rendered the peasants less exposed to famine from the destruction of their crops by hailstorms. Resuming the study of electricity, he discovered the condenser in 1778, while trying to improve the electrophorus. He employed marble or varnished wood as the dielectric in preference to resin, which he had used in the electrophorus. The condenser was a useful instrument in Volta's hands, since it enabled him to accumulate feeble charges of electricity until they could produce a sensible effect. It was described in the *Philosophical Transactions* for 1782, and Volta there observes that by its aid he had detected electricity in the vapour of water, the smoke of coal, and the gas of iron dissolved in weak sulphuric acid.

In 1779, Volta was appointed to the chair of Physics in the University of Pavia; and the following year he travelled in Tuscany, where he visited the Pietra Mala or Vilicya, and showed that the gases disengaged there are not due to petroleum in the soil. In 1782 he travelled in company with Scarpa to Germany, Holland, and England, where he collected apparatus for his laboratory, and met the most eminent men of science. On his return through Paris he succeeded in showing before Lavoisier and Laplace, that electricity was produced by the evaporation of water in a basin. He imagined that he had now discovered the source of atmospheric electricity; but there is reason to believe that the electricity his condenser enabled him to find, came rather from the friction of the vapour on the sides of the vessel than from evaporation. His subsequent letters to Lichtenberg on *Meteorologia Electrica* are his next important work. They show that Volta not only improved the electrometer by substituting a pair of diverging straws for the pith balls then employed as an index, but also added a scale for measurement; they teach us what is not so well known—that he was the first to make an absolute electrometer, in which the electrical attraction is actually weighed in a balance.

Volta's observations on the power of flames to discharge electricity led him to apply a burning fuse to the electrometer of Cavallo, and to suggest that bonfires should be kindled on the tops of hills, in order to discharge a thundercloud, instead of lightning rods.

In 1791, he was elected to the Royal Society; and three years later received the Copley Medal for his discoveries—which now included the law of Charles on the dilatation of gases under heat.

On September 22nd, 1794, Volta espoused Teresa Peregrini, a lady of noble birth and slender fortune. She bore him three sons, Giovanni, Zannino, and Flaminio, to whom he was much attached. He was more than a father to them; he was their teacher, friend and comrade. In their walks together he would be seen in their midst, propounding some question in science, or reciting some passage from the *Æneid*, or the *Jerusalamo*. The death of Flaminio, a promising mathematician, at the age of eighteen, was the poignant sorrow of his life.

Volta had now started on his immortal work, the discovery of the pile, or chemical source of electricity. He believed, with Franklin, that electricity resided in all natural bodies in a state of equilibrium, and became sensible when that balance was disturbed; for example, by friction. He had long supposed there might be other means of drawing forth the secret fire which was lurking in the labyrinth of matter. But hitherto his attempts to obtain it by chemical action and evaporation had only yielded very feeble results. A better clue was put into his hands by a compatriot.

Luigi, or Aliosio, Galvani was born at Bologna on September 9th, 1737, of a family which had produced several distinguished men of letters. As a youth he was very devout, and intended for the cloister, but while studying theology at the University he fell in love with *Lucie Galeazzi*, the daughter of his friend and [illegible], whom he married at the age of twenty-three. Having graduated [illegible] he studied medicine and took his doctor's degree in [illegible]. Some researches on the [illegible] of the organ of hearing and the [illegible] procured him a reputation and a lectureship in the Institute of Bologna. He was subsequently appointed to the chair of anatomy in his *alma mater* and became a [illegible], but an eloquent teacher, besides practising as a doctor in the town.

It appears from documents in the Institute of Bologna that Galvani had studied the effects of electricity on the limbs of frogs as early as the year [illegible]; but a story is current which refers these experiments to a later date and traces their origin to a happy chance which, if true, shows how a trifling observation, properly followed up, may lead to a great discovery. The story has as many versions as the [illegible] of [illegible] and the [illegible], but the gist of it is that Madame Galvani, being in delicate health, the legs of some skinned frogs were ordered to make her a strengthening soup, and as they were lying in Galvani's laboratory, an assistant happened to touch one of them with a scalpel, when to his surprise he saw the limb convulsed. Sparks were being drawn from an electrical machine which was standing near, and at every spark there was a twitching of the limb. Galvani's attention was called to the curiosity, and he subsequently noticed a similar twitching in some limbs hung by copper skewers from an iron rail. In this case there was no electrical machine, and Galvani also satisfied himself that the effect was not due to atmospheric electricity. He showed that it was invariably produced by an arrangement known as the 'metallic arc.' It consisted in touching the nerve of the limb with a rod of zinc and the muscle with a rod of copper, then bringing the two metals into contact. Galvani seems to have been struck with the resemblance of this experiment to the discharge of a Leyden jar, by connecting its two coats with a wire. He compared the nerve to the inner coat positively electrified, the muscle to the outer coat negatively electrified, and the metal arc to the discharging wire. In fine, he came to the conclusion, as a physiologist, that he had discovered the existence of 'animal electricity.'[1]

His ideas were published in the eighth volume of the *Memoirs* of the Institute of Bologna under the title of 'Aloysii Galvani, De Viribus electricitatus in motu musculari Commentarius.' The work appeared in 1791, and created a profound sensation, not only in scientific circles, but amongst the people. There was something startling in the fact that the limbs of creatures which had long been dead could be compelled to move and act as though they were alive. Many suspected that Galvani had found out the secret of the nervous force and the action of the muscles, while others believed that he had solved a still greater mystery, and did not hesitate to declare that electricity was life.

The electrician of Pavia repeated the experiments of the anatomist of Bologna, and with better apparatus, for he was able to collect the feeble electricity with his condenser and measure it with his diverging-straw electrometer. Influenced no doubt by his past labours and thoughts upon electrical production, Volta challenged the theory of animal electricity. He regarded the frog's limb merely as a delicate electroscope that showed the presence of the electricity, which he maintained was generated by the contact of the two dissimilar metals.

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[1] In 1678 Swammerdam, before the Grand Duke of Tuscany, showed the convulsion of a frog's muscle by holding it against a brass ring from which it hung by a silver wire. Du Verny in 1700, and Alex. Stuart, M.D., also proved this effect before Galvani. [*Phil. Trans.* 1732.]

Galvani picked up the gauntlet: and thus began one of the most decisive battles which has ever been waged in the interests of science.

Volta refuted the hypothesis of Galvani, which likened the nerve and muscle of the limb to the coatings of a Leyden jar, by producing the convulsion with two dissimilar metals both touching the muscle, and leaving the nerve alone. Galvani replied by pointing out that two dissimilar metals were unnecessary, since the effect took place with pieces of the same metal. Volta attributed this anomaly to a difference of temper or polish in the two plates, which caused them to behave in the manner of different metals. Others beside the two chiefs engaged in the conflict: and Dr. Valli induced the twitching by bringing two portions of the frog in contact, without employing metals at all. There was great jubilation in the camp of the Galvanists over this discovery, which appeared to settle the question. But Volta was not dismayed. He responded by showing that the two parts of the frog must be unlike, for their contact to produce the twitching; and he extended his contact theory from metals only to all heterogeneous substances.

The Galvanists were silenced, but not subdued, and they continued to hug their darling error, while venting their activity in galvanising the heads of bulls and other slaughtered animals into a mockery of life.

Volta had won the victory, and with it a new domain for science. He had discovered a new mode of generating electricity by the simple contact of two dissimilar bodies, without the aid of friction, and this eventually brought him to the invention of the pile.

Galvani held a great discovery between his hands, and lost it through a misinterpretation. He clung to his mistaken theory until the end; and in 1797 he made a journey along the Mediterranean for the purpose of investigating the structure of the torpedo, an electric fish known to the ancients, and formed the opinion that the brain itself was a source of animal electricity. This was the saddest year of his life, for soon after his return home his beloved wife and companion of so many years was taken from him. Another calamity followed on her death. The government of the new Cisalpine Republic exacted an oath of allegiance from its servants, which he, on conscientious grounds, declined to take. Dismissed from his professorship, and broken alike in heart and fortune, the amiable Galvani retired to the house of his brother Giacomo, and fell into a decline. Repenting of their brutality, the government of the republic restored him to his office; but it was too late; Galvani died before resuming his chair, on December 9th, 1798.[1]

A brighter destiny awaited his successful rival. In seeking to augment the electricity obtained from the contact of dissimilar substances, Volta devised the 'corona,' or crown of cups, a battery consisting of a series of cups, containing a saline solution, in which plates of zinc and silver were dipped edgewise. Each silver plate of a cup was connected with a wire to the zinc plate of the next cup, and the terminal plates of the series, zinc and silver, formed the poles of the battery, from which a copious supply of electricity was drawn. An account of it was sent to the Royal Society in the year 1800; but owing to the war between France and Great Britain the full description was delayed, and in the interval he constructed the 'pile,' a battery which superseded it. The pile consisted in plates of zinc and copper laid one above the other in the same order, with moistened cloth between them. No wires were needed to connect the plates, which formed a simple pillar of discs, like a pile of coins, and the electricity was drawn from the terminal plates of copper and zinc, which made the positive and negative poles of the battery.

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[1] A complete edition of his works was published at Bologna in 1841–2.

An account of the pile, given in a letter to Sir Joseph Banks, appeared in the *Philosophical Transactions* for the same year. It was one of the great inventions of the world, like the telescope and the steam-engine, and soon gave birth to an infinite number of applications and improvements. The frictional machine and the electrophorus had, indeed, produced electricity before the pile, and the Leyden jar had stored it. But it was an electricity very difficult to manage. It was too intense for practical purposes, and ran into a series of disunited sparks. The electricity from the pile, on the other hand, was of a mild and docile nature; it flowed in a continuous current, easily controlled. We may compare the electricity of friction to a sudden jet of water at high pressure, and the electricity of the pile to a broad and gentle stream. The prediction of Stephen Gray was now verified in a fuller sense, perhaps, than he intended.

The powerful current of the pile was soon applied to excite the muscles of the dead, after the manner of the Galvanists. On one occasion the head of a criminal was convulsed into a grimace so horrible that many of the spectators fled in terror, and one is said to have gone mad. The trunk of the victim partly itself, the arms flew out, and the hands struck against the neighbouring objects. Various acts of life, such as breathing, were simulated, and people began to ask if all sensation was extinct, and whether it was legitimate to make experiments which might in reality be torture.

A curious observation made by Sulzer many years before was now explained. Sulzer pointed out that when a coin was placed over the tongue and brought into contact with another coin of a different metal under the tongue, a peculiar alkaline or acid taste was felt in the mouth.[1] The combination of the two metals and the damp tongue formed in effect a single couple of the voltaic pile, and the taste was due to chemical decomposition produced by the electric current. The sharp flavour of porter drunk out of a pewter pot was accounted for on the same principle.

Volta was now on the high road to the most dazzling honours. In 1796, when Buonaparte entered Italy, he had been sent as a deputy from the city of Pavia to solicit the young conqueror's protection. Buonaparte never forgot this, and when he was created First Consul he summoned Volta, in 1801, to Paris, to exhibit his experiments with the new pile before the members of the Institute of France. Buonaparte himself was present at the *séance*, and on the termination of the lecture rose and proposed that a gold medal of the Institute should be struck in Volta's honour, and that 2000 crowns be given him for his travelling expenses. Volta was afterwards elected a member of the French Institute, and Buonaparte conferred upon him the cross of the Legion of Honour and the order of the Iron Crown. He also nominated Volta as a delegate from the University of Pavia to the Congress of Lyons, which selected a president for the new Italian republic. Nine years later, in 1810, when Buonaparte was emperor, he created Volta a count and senator of the kingdom of Italy. Napoleon's interest in Volta had something of affection. During a visit to Italy in 1804, when the members of the Italian Institute presented themselves at the palace where he resided, Buonaparte, not seeing Volta in the fronk ranks, cried with an air of disappointment, 'Where is Volta? Is he ill? Why has he not come?' About this time Volta wanted to retire from his professorship, but Buonaparte refused his consent. 'If Volta's functions fatigue him,' said he, 'they must be reduced. Let him only give one lesson a year if he likes; but the University of Pavia will be struck to the heart the day I permit his name to disappear from its calendar. For the rest,' he added, 'a good general ought to die on the field of honour.' On his third visit to Italy the emperor stopped at Pavia, and visited the University. When he saw the pupils of Volta, he put his hand lovingly on the philosopher's shoulder, and exclaimed: 'Bravo, Volta! Bravo! you are worthy to be the instructor of youth.'

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[1] *Nouvelle Théorie des Plaisirs.* Berlin, 1767.

Volta was fitted to attract both love and admiration. In person he was tall and handsome, with noble features and the refined air of a gentleman. On the wide and furrowed brow, in the calm but penetrating eye, one could read the serenity and greatness of his mind. Simple, affectionate, and sincere, his character had never been corrupted by the vulgar passions. Ambition, greed, or envy did not move him. An ardent love of home and science had purified his heart from worldly dross. Even his honours did not spoil him, and the habits of his boyhood still clung to him in the days of his renown. While he was being lionized in Paris he would sometimes go into a baker's shop to buy a plain loaf, and eat it on the street. Genius is always attractive to the young, but it becomes fascinating when allied to modesty and courteous manners. No wonder, then, that Volta was idolized by his students, or that throughout all Italy he was called familiarly 'Our Volta.'

With a fine appearance, and a clear unstudied eloquence, Volta might have shone in public life; but he never had a taste for it. Newton is said to have spoken but once in Parliament, when he asked the verger to close a window which made a draught on the member who addressed the House. Volta never spoke at all. Although the times were stormy, he did not attach himself to any political party, and he avoided the subject of politics even in private.

Volta was in love with home and a contemplative life. More fortunate than Franklin, whose career is a striking contrast, he was able to gratify it during many years. Other compliments were paid to him besides those of Napoleon. The Emperor Francis of Austria appointed him Director of the Faculty of Philosophy in the University of Padua. He received a flattering invitation from St. Petersburg, but he declined to leave Italy. At length, in 1819, he retired to his native town, where he spent the remainder of his life.

The invention of the pile had put into his hands a new and splendid engine of research, and it is remarkable that Volta did not employ it in making fresh discoveries. He amused himself with trifling experiments in galvanism on dead animals, such as making a cricket sing, or increasing the lustre of a beetle; while Carlyle and Nicholson were decomposing water, and Humphry Davy was separating the alkaline metals, sodium and potassium, from their earths.

Some have thought that the invention of the pile exhausted Volta's faculties; for, beyond two papers on hail and storms, he contributed nothing more to science. The secret of his idleness lies, probably, in his domestic inclinations. In later life, he appears to have lived only for his family, secluded from the world, and hardly accessible to visitors of distinction. His mind began to fail during his last years, and in the summer of 1823 he was stricken with apoplexy. Rallying from this, and from a mild attack of jaundice in the autumn of 1826, he died of fever on the 5th of March, 1827, after a few days' illness. He was buried with great pomp in the churchyard of Camnago, a village near Cámpora, the country seat of his family, in the neighbourhood of Como. A fine monument was afterwards erected to his memory, and his apparatus, including the first pile, have been preserved in the palace of Brera, at Milan.

Volta was happy and fortunate in his life, and deeply lamented in his death. He was a man of even piety and virtuous disposition. Gifted with genius, he was not denied the spirit of order and perseverance. He excelled as an experimenter, and his discoveries are the result of sound reasoning upon observed facts. As a theorist he was not successful, and even in the case of the pile, his opinion that the electricity is solely due to contact of the metals is now known to be fallacious, since chemical action comes into operation. Nor was he a mathematician; and it was left to Coulomb to develop the methods of electrical asurement. He lived to see his great discovery ducing a rich harvest in the hands of Davy, Oersted, Ampère. Its novelty was never questioned, but ta was always ready to acknowledge with admiration his indebtedness to Galvani. A grateful posterity have perpetuated his memory by calling the practical unit of electromotive force a 'volt.' His collected works were published at Florence in 1816, and dedicated to the Grand Duke of Tuscany.

SIR HUMPHRY DAVY.

SIR HUMPHRY DAVY.

VOLTA, as we have seen, discovered the mode of generating electricity by chemical action; but it was left for Humphry Davy to reverse the process, and, by employing the current thus obtained, to break up chemical combinations and establish the new science of electro-chemistry.

Davy, the eldest son of Grace and Robert Davy, was born at Penzance, near the Land's End, on the 17th of December, 1778, about 5 o'clock in the morning, by the register of his father in the family Bible. His forbears held a small estate at Varfell, on Mount's Bay, where a tablet in the church to the memory of one is dated 1635. His grandfather was a builder, and is said to have designed the mansion house of Trelissick, near the town of Truro. His father, Robert, had been apprenticed to a wood-carver in London, but the art was declining, and on coming into a modest patrimony, on the death of his father, he gave up the business and retired to Penzance, where, being short of stature, he was called 'the little carver.' He was a quiet man, inclined, they say, to idle habits, and did not foreshow the eminence of his son; but Grace Millett, his wife, was remarkable for her amiable and benevolent disposition. She came of a good but impoverished family, and had been -dopted by Mr. John Tonkin, an apothecary and geon in Penzance, with whom she lived until her riage. Humphry was a healthy, active child, ed by his mother. He could walk when he was nine months, and speak well when he was two years old. Like Pope, he 'lisped in numbers,' and also busied himself in copying the plates of *Æsop's Fables*, and the *Pilgrim's Progress*, which was his first book. Though forward in mind and body he was a good-tempered little fellow, and a general favourite. At five he was sent to learn reading and writing at the school of Mr. Bushell, an old man, and after a year there, to a grammar school in Penzance, kept by the Rev. J. C. Coryton, a gentleman who had a trick of pulling the boy's ears. One day little Davy appeared in his class with enormous patches of sticking-plaster on his ears. The master inquired what was wrong, and the boy replied that he had put on the plaster 'to prevent mortification.' Coryton, it seems, was not an able teacher, but Davy never regretted it. 'After all,' he wrote to his mother in 1802, 'the way in which we are taught Latin and Greek does not much influence the important structure of our minds. I consider it fortunate that I was left much to myself when a child, and put upon no particular plan of study, and that I enjoyed much idleness at Mr. Coryton's school. I perhaps owe to these circumstances the little talents that I have, and their peculiar application. What I am I have made myself; I say this without vanity, and in pure simplicity of heart.' Being quick to learn, he soon mastered his lessons, such as they were, and gave the rest of his time to play and his own devices. He was a famous writer of love-letters and valentines for his schoolmates; and often of an evening they would wait for him beneath the balcony of the old Star Inn, nearly opposite his birthplace, in Market Jew Street, to hear the tales of chivalry he would recite to them from some carrier's cart. Most of the stories were out of books, or gathered from Grandmother Davy, a woman of strong poetical mind, well stocked with the legends of her native county; but some of them were of his own creation. 'I never loved to imitate, but always to invent,' he once wrote: 'this has been the case in all the sciences I have studied.' At times he and the other boys would sally forth like the Paladins of old in quest of adventures. They tilted in 'tournaments' with wooden lances, and armed in pasteboard shields and visors. Once, too, they played a pantomime, in which Davy performed the part of harlequin. In all these sports we may be sure he was the ringleader; the squibs and crackers he made on wet days in an empty room; the tin he smelted out of stones picked up in the streets before an audience of girls and boys who had paid at the door in pins; the turnip lantern he had carved with a jack-knife, were among his earliest scientific efforts.

At the age of nine he lived with Mr. Tonkin, his parents having removed to Varfell, where he usually went to spend his holidays. Mr. Tonkin befriended the son as he had befriended the mother, and kept him for a year at the grammar school at Truro, under the Rev. Dr. Cardew, where he finished his education at the age of fifteen. Dr. Cardew considered him a good, intelligent boy, but no prodigy. His best exercises were translations from the Greek and Latin into English verse. A certain originality of thought and action, noticed by some of his associates, appears to have escaped the master.

At this time Davy showed a general aptitude for everything, but no particular bent. He would sketch in colours, draw caricatures, make poetry, and pore over books, especially histories. He would shut himself in a room, mount a chair, and lecture to nobody. e would collect rare birds and stuff them himself, he uld haunt the rocks near the Botallack mine, and collect odd minerals. It is significant, however, that, according to his remark to Dr. Paris, he would sometimes sit down upon the turf and dream of scientific fame.

An ardent sportsman all his life, he was fond of fishing as a boy, and when quite a child would dangle a bent pin in the gutter. He was a good shot, and used to scour the sands and marshes after waterfowl. Here, then, was an interesting and capable boy, a young genius of the Land's End, meant for an intellectual life of some kind. Let us see what will befall him.

For a year after he left school he idled about, 'unfitted with an aim': now meditating by the sea or in the woods, anon shooting or fishing, and sometimes playing billiards or keeping dangerous company. It was a critical period, which might have marred his whole career; but his better genius prevailed. The death of his father in December 1794, and the poor circumstances of the family, doubtless helped to steady him. He resolved to acquire knowledge and to do his best.

He began by taking lessons in French from a Breton refugee, and finally chose a profession. His mother had come to live at Penzance, and, by the advice of Mr. Tonkin, Davy was apprenticed on February 10th, 1795, to Mr. Bingham Borlase, a surgeon-apothecary of the town, who afterwards practised as a physician.

Davy was now in the spring of youth, when life begins to burgeon, and the golden prospects of coming manhood open to the imagination. An impulse toward self-improvement is as natural at this period, especially to an aspiring youth, as constant movement to a child. Both are agents in the development of the creature. Stirred by a new and larger growth within him, Davy felt a desire to cultivate all the faculties of his mind and body; but his studies were systematic, not perfunctory, as too often happens, and they were pursued with zeal, and not by fits and starts. The course of reading which he planned for himself embraced the entire circle of knowledge, from theology and metaphysics to chemistry and medicine. He seems to have worked his way through part of it, at least, not slavishly, but with a pregnant mind, for his note-books of that date are filled with themes for essays, jottings on philosophy, poems and fragments of Arthurian romance. The titles of these essays mark the instability of his opinions at the time. One is on the immortality of the soul, another in defence of materialism. He was never wedded to an opinion. 'Consistency in regard to opinions,' he afterwards wrote, 'is the slow poison of the intellectual life, the destroyer of its vividness and its energy.' He also hunted and fished, and joined the volunteers. Being rather awkward in his gait, he hired a sergeant to give him private lessons in the drill. Davy had the making of a soldier in him, for he lacked neither physical nor moral courage. One day he was bitten by a dog, and promptly cut out the part with his pocket-knife, then cauterised it in the surgery. At this time, his voice being harsh and unmelodious, he cured it, like Demosthenes, by speaking to the waves. Like many a genius, he was fond of his own company, and the thoughts which came to him in solitary places. Thus he would often wander along the sea-shore to Marazion, where his aunt lived, now stooping to pick up a mottled stone of serpentine or agate which the tide left wet and gleaming, anon musing on the castled crags of St. Michael's Mount, which loomed out of the misty bay like some giant's keep or weird Cornish rnassus. One of his favourite spots, we are told, was the little glen of Gulvalcarne, where he would fling himself down beside the brook and fashion a rhyme or meditate over a point of science.

He fell in love with a young French lady of Penzance, probably a daughter of the refugee, and wrote a number of sonnets, which have been lost. Some of his poetical pieces were afterwards published in the *Annual Anthology*, at Bristol, in 1799, a work edited by Southey and James Tobin. Dr. Paris tells us that a great poetic genius (Southey, perhaps, or Coleridge) had said, 'If Davy had not been the first chemist, he would have been the first poet of his age.' But it is never safe to make assertions of this kind; and if we may judge by these remains, Davy might have been anything, for aught we know, except a poet. Dr. Paris shows himself no wiser in asking, 'Where is the modern Esau who would exchange his (Davy's) Bakerian lecture for a poem, though it should equal in design or execution *Paradise Lost?*' It is folly to compare a scientific discovery with a poem, or any unlike things of which the values are inestimable. If Davy had not decomposed the alkaline earths, another would before long; but none save Milton could have written *Paradise Lost.* The first of his poems is entitled the *Sons of Genius*, and bears the date of 1795. A verse or two will satisfy the reader's curiosity. After depicting the starlit night, it runs:—

'Now the poor shepherd, wandering to his home,
Surveys the darkening scene with fearful eye,
On every green sees little elfins roam,
And haggard sprites along the moonbeams fly.

While Superstition rules the vulgar soul,
Forbids the energies of man to rise,
Raised far above her low, her mean control,
Aspiring Genius seeks her native skies.

* * *

For those exist whose pure ethereal minds,
  Imbibing portions of celestial day,
Scorn all terrestrial cares, all mean designs,
  As bright-eyed eagles scorn the lunar ray.

Theirs is the glory of a lasting name,
  The meed of Genius, and her living fire;
Theirs is the laurel of eternal fame,
  And theirs the sweetness of the Muses' lyre.'

These are the sentiments of an aspiring youth, imbued with poetical feeling, and already conscious of possessing genius. They are remarkable verses for a lad of seventeen; and at this time Davy seems to have believed himself a poet. But in a later *Ode to St. Michael's Mount* we find a change of purpose.

'The sober Eve with purple bright
Speeds o'er the hills her tranquil light
In many a lingering ray;
The radiance trembles on the deep,
Where rises rough the rugged steep,
Old Michael from the sea.

* * *

Majestic steep! Ah! yet I love
With many a lingering step to rove
Thy ivied rocks among;
Thy ivied wave-beat rocks recall
The former pleasures of my soul,
When life was gay and young.

Enthusiasm, Nature's child,
Here sung to me her wood songs wild,
All warm with native fire;
I felt her soul-awakening flame:
It bade my bosom burn for fame,
It bade me strike the lyre.

* * *

Thus to the sweetest dreams resigned,
The fairy Fancy ruled my mind,
And shone upon my youth;
But now to awful Reason given,
I leave her dear ideal heaven,
To hear the voice of Truth.

She claims my best, my loftiest song,
She leads a brighter maid along—
DIVINE PHILOSOPHY,
Who bids the mounting soul assume
Immortal Wisdom's eagle plume,
And penetrating eye.'

These lines evince a poetical feeling for Nature and a good imagination; but the descriptions are too cold and servile, the ideas too conventional and trite, for poetry. We miss the daring originality of thought, the fire and beauty of expression, which marks the heaven-born singer. Even the rhythm shows that his Pegasus was trotting along the road instead of soaring into the virgin fields of ether. Davy's verse is little more than the philosophy of a refined poetic temperament. If a man is not poetical in the flower of his youth and the inspiration of his first love, when will he be? But though Davy afterwards became a distinguished writer of prose, and might have been a successful man of letters, he would probably have failed as a poet. On the whole we think he found his true vocation.

There was a central bud of philosophy in his genius, a heart for truth, which ultimately grew into the main stem of his intellectual life. Even as a boy, in bathing, he would discourse to his companions on the Newtonian theory and the causes of the tides. The drug shop helped to confirm his scientific bent, by bringing him in contact with chemicals and their properties. He intended to become a doctor, and his general studies were tapered down to the sciences likely to be most useful to him. In 1796 he had taught himself mathematics and metaphysics. In 1797 he took to natural philosophy and chemistry. Lavoisier's *Elements of Chemistry* produced a deep impression on his mind, and he began to experiment in a garret at Mr. Tonkin's house.[1] His apparatus was of the homeliest order, phials, wine-glasses and tobacco-pipes; but his explosions were so successful that Mr. Tonkin would exclaim, 'That boy Humphry is incorrigible: he will blow us all into the air.' At other times Mr. Tonkin would flatter him with the title of 'Philosopher' and 'Sir Humphry.' He began with the experiments of the books; but soon devised others of his own. 'I never loved to imitate, but always to invent,' he wrote in one of his note-books; 'this has been the case in all the sciences I have studied.'

Just then he made the acquaintance of Mr. Gregory Watt, a son of the celebrated James Watt, improver of the steam engine, who, being in delicate health, was spending the winter at Penzance, and boarded with Davy's mother. He was only a year or two older than Davy, and had been educated at Glasgow University. The pair became fast friends, and being both lovers of science and literature, they were often together, collecting minerals at the mines, and discussing the problems of chemistry. This friendship afterwards proved useful to Davy, as did that of an older man, Mr. Davies Gilbert, who subsequently became his successor as President of the Royal Society. This gentleman happened to pass one day while Davy was amusing himself by swinging on the gate of his master's house, and making funny faces. At this time he was far from comely, with round shoulders, a discordant voice, and an insignificant manner. Mr. Gilbert, however, asked who he was, and was told, 'Young Davy, the carver's son,' and that he was fond of chemical experiments. 'Chemical experiments!' echoed Mr. Gilbert, in surprise, and began to talk with

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[1] It stood near the foundation stone of the present New rket House, Penzance.

Davy. By-and-by he offered the young philosopher the use of his library, and invited him to his residence at Tredrea, where he was introduced to Dr. Edwards, of Hale Coppes House, who showed him his laboratory, and sent him into ecstacies over the first air-pump he had ever seen.

Davy was a disbeliever in the current theory that heat was an issue of material corpuscles from an incandescent body. He considered them as molecular phenomena; and one of his first experiments was to melt ice in a vacuum with the heat generated by friction. The air-pump he employed to produce the vacuum was made by himself out of an old glyster or syringe, presented to him by the surgeon of a French vessel which had been wrecked off Land's End. Necessity being the mother of invention, this lack of means sharpened the young experimenter's wits, and developed his constructive talent.

Mr. Watt sent an account of these experiments to his friend Dr. Beddoes, who had founded the Pneumatic Institution, at Clifton, for the cure of diseases by administering gases. Beddoes was much impressed with them, and through Dr. Gilbert offered Davy the post of laboratory assistant at the Institution. Davy welcomed the appointment with delight, as an opening to fame and fortune, and only stipulated for a 'genteel maintenance.' His mother was pleased; and Mr. Borlase generously cancelled his indentures; but Mr. Tonkin, disappointed in his hopes of seeing Davy a doctor in his native town, discountenanced the offer, and, altering his will, revoked a legacy in the boy's favour. Nevertheless he lived to see his former protégé appointed to the Royal Institution.

Davy's last months in Penzance were among his happiest. He had won the esteem of Mr. Borlase, and the good word of the poor. A career fit for his talents was opened up to him, and his visions of a distinguished future appeared about to be realised. 'I have neither riches, nor power, nor birth to recommend me,' he wrote, 'yet if I live I trust I shall not be of less service to mankind and to my friends than if I had been born with these advantages.'

On the 2nd of October, 1798, at the age of twenty, he took the coach for Bristol, and passing through Okehampton two days later, heard the news of Nelson's glorious victory on the Nile. At Clifton he was treated as a friend by Dr. Beddoes and his amiable wife, whom Davy regarded as a second mother. At their house he enjoyed intellectual society, and made some valuable acquaintances, including the poets Southey and Coleridge. The Pneumatic Institution consisted of a hospital for the patients, a laboratory, and a lecture theatre. Davy superintended the experiments on the medical virtues of different gases; but was free to make original investigations of his own. He formed his scientific method of working here; and his note-books teem with suggestions for future experiments, even to the decomposition of the alkaline earths. Like most young physicists, he had begun with speculation; but he soon learnt to rely solely on experiment. 'When I consider the variety of theories on the slender foundation of one or two facts,' he wrote, 'I am convinced that it is the business of the true philosopher to avoid them altogether. It is more labour to accumulate facts than to reason concerning them; but one good experiment is of more value than the ingenuity of a brain like Newton's.' The true method is to reason upon facts, and test the reasoning by experiment. For, as he himself remarks elsewhere, 'It is only by forming theories, and then comparing m with facts, that we can hope to discover the true em of Nature.'

He made some laughing-gas (nitrous oxide), and has described his sensations on breathing it. 'I know,' he remarks, 'that my motions were various and violent.' Southey and Coleridge also breathed the Pythian fumes, but only laughed a little. Davy made himself ill by inhaling nitric oxide; and nearly lost his life with carburetted hydrogen. His first scientific papers were published in 1799 in the *Contributions to Physical and Medical Knowledge*, collected by Dr. Beddoes; but these essays on the nature of heat and light, on oxygen and its combustion, and the theory of respiration were afterwards stigmatised by their author as the 'dreams of unemployed genius.' The errors of such a man, however, may be useful in encouraging other tyros. He pronounces light material, but not heat, and calls its union with oxygen phos-oxygen, a substance which combines with venous blood. On reaching the brain, the light is liberated in the form of electricity, which he believes to be identical with the nervous fluid! He was more successful in his *Researches, Chemical and Philosophical*, published in 1800; and that on the *Absorption of Nitrous Gas by solutions of Green Sulphate of Iron*, may be studied with profit by the young experimenter. Volta's great discovery of the pile placed in the hands of Davy an instrument of research which he was to use with splendid effect. In a letter to Mr. Davies Giddy, of Oct. 20th, he writes, that 'charcoal is a good galvanic exciter, and decomposes water, like the metals, in the pile.'

Davy's friends and publications had introduced him to the notice of the leading men of science; and Count Rumford, who was then looking out for a rising lecturer in chemistry to increase the reputation of the newly-founded Royal Institution of London, engaged him as the director of the laboratory and assistant-professor of chemistry. Davy would accept no appointment save on the 'sacred terms of independence,' and his salary was fixed at a hundred guineas per annum, besides a room in the Institution, rent free, with coal and candles. This appointment threw the ardent young chemist into a 'fever of emotion.' He saw himself within reach of the summit of his ambition, a life devoted to science and the welfare of his fellow-men. His duties were light, and limited for the most part to the spring and winter of each year; while he was allowed the free use of the apparatus for his own experiments. He resolved to devote his powers to promote the interests of the Institution, and being absolved from his Clifton engagement by Dr. Beddoes, entered on his duties on the 11th of March, 1801.

Count Rumford had been influenced in his choice by gentlemen who had met Davy at Clifton, and biassed perhaps by Davy's views on heat coinciding with his own. But he was keenly disappointed with the pert and smirking appearance of the boyish philosopher.[1] On hearing him lecture, however, he cried out: 'Let him command any arrangements which the Institution can afford.' In June Davy was 24 promoted to be Lecturer on Chemistry.

In his introductory lecture he depicted the chemist as ruler of all the elements around him, and employing them for the satisfaction of his wants or the gratification of his desires. It was delivered to a brilliant and fashionable audience in the great theatre of the Institution, and there and then established his reputation. 'The sensation created by his first course of lectures at the Institution,' says Mr. Purkis, 'and the enthusiastic admiration which they obtained is at this period hardly to be imagined. Men of the first rank and talent, the literary and the scientific, the practical and the theoretical, blue-stockings and women of fashion, the old and the young, eagerly crowded the lecture-room. His youth, his simplicity, his natural eloquence, his chemical knowledge, his happy illustrations and well-conducted experiments, excited unusual attention and unbounded applause. Compliments, invitations and presents were showered upon him in abundance from all quarters; his society was courted by all, and all appeared proud of his acquaintance.'

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[1] Dr. Paris, *Life of H. Davy.*

The novelty of the Institution and the growing taste for science rendered the time propitious; but the secret of this extraordinary success lay chiefly in the lecturer. The man himself was interesting as a scientific prodigy. People were curious to see this Roscius of the crucible, this philosopher with the down upon his cheek. His boyish aspect was in striking contrast to the brilliancy of his discourse, the dignity of the rostrum, and the arcana of the laboratory, the sparkling intelligence of his eye, the animation of his movements, and the naturalness of his manner captivated the attention. The style of his exposition was as entertaining as the matter was instructive. His language was clear, polished, and frequently poetical. Coleridge said that he went to hear Davy, to increase his stock of metaphors. He enlivened the subject with anecdotes of the great chemists, illustrated it with fascinating experiments, and did not scruple to elevate it by impressive declamation on the beauty and design of Nature, as the handiwork of the Great Artificer. Carpers said his style was too florid, but Davy lectured to a popular audience, and had to foster the taste for science. He endeavoured to attract in order to inform, and sought to maintain the dignity of his theme. Even while most amusing he was in earnest, and expected the like of his audience. His language was not intended to catch applause, and his showiest experiments were meant to illustrate a principle or property of matter.

With his double gift of eloquence and experimental genius, Davy was the right man in the right place. The special requirement of a lecturer is that he shall be able to lecture. It is not enough that he shall know his subject thoroughly. If he be tongue-tied, like Dr. Young, and cannot communicate it to others, he is unfit to teach. It is not enough that he shall be an original investigator, for that will only help him to extend his knowledge and to devise experiments. Study of the works of others, experimental skill, and the arts of expression, are all requisite to his success, and hence it was that Davy, with his literary talent, his oratorical exercises at Penzance, and his experimental practice at Clifton, became one of the creators of the popular science lecture, and made the Royal Institution of Albemarle Street a rival to the Opera House. He took great pains over the work. At first he wrote his lectures the day before, dining sparely on fish in his own room; but latterly he trusted to his notes, only preparing the more eloquent passages. He always rehearsed them beforehand, to ensure the success of the experiments and improve his oratory.

Petted by the fashionable, and courted by the great, it is not surprising that Davy, who had served the counter two years before, should be a trifle lifted up and spoiled by his celebrity. His vanity was flattered, and his ambition blown by the applause and adulation of society. In his leisure hours he affected the man of fashion, played billiards, read the last new novel, and showed himself at Ranelagh. The soirées of the Duchess of Gordon were reckoned incomplete without him. Friends saw with regret that his manner had lost some of its old frankness and simplicity, and Sir Harry Englefield has described an evening they spent together at Blackheath 'as the last flash of expiring Nature.' But under all it seems that his better feelings were untouched, and his allegiance to his work unshaken. He was always back in his laboratory next morning, and in a letter to Mr. Poole, dated May, 1803, he says: 'Be not alarmed, my dear friend, as to the effect of worldly society on my mind: the age of danger has passed away. There are in the intellectual being of all men paramount elements—certain habits and passions that cannot change. I am a lover of Nature, with an ungratified imagination. I shall continue to search for untasted charms, for hidden beauties. My *real*, my *waking* existence is amongst the objects of scientific research. Common amusements and enjoyments are necessary to me only as dreams, to interrupt the flow of thoughts too nearly analogous to enlighten and vivify.' Elsewhere he writes of the temptations of great cities, 'An active mind, a deep ideal feeling of good, a look towards future greatness, has preserved me. I am thankful to the Spirit who is everywhere that I have passed through the most dangerous season of my life with but few errors, in pursuits useful to mankind, pursuits which promise me, at some future time, the honourable meed of the applause of enlightened men.'

In his new position he had soon applied himself to original research. The *Journal* of the Royal Institution, which he helped to edit, contained an account of his new eudiometer, based on the discovery he made at Clifton, that oxygen is absorbed by a solution of green sulphate of iron impregnated with nitrous gas. His first paper to the Royal Society, read in June, 1801, describes a new 'galvanic combination' of two fluids and two plates of the same metal, the cells being arranged as a trough battery. In November, 1803, he was elected a Fellow of the Royal Society. His 25 duties at the Royal Institution at this time included the delivery of lectures on the chemistry of tanning and of agriculture, subjects which he illuminated. He did not come altogether scatheless from his experiments. On one occasion he injured his hand with melted potash, and on another his eye from the detonation of a compound.

His versatility was equally remarkable. A friend calling on him one day, happened to mention that the prologue for the production of the *Honeymoon* was not yet written. Davy quitted the laboratory to write one, and in two hours returned with the piece, which was ultimately spoken.[1] He was still ambitious of being thought a poet, and composed many verses which passed among his friends.

On leaving the Institution he dropped its cares behind him, and spent the evening after his own humour, or in society. During the vacation he would make excursions into the country, sometimes with a knapsack and a friend on foot; and in the course of these rambles he visited his native county, Wales, Ireland, and Scotland. He was a keen fly-fisher, partly for sport, partly to rest his mind; but he also sketched, visited romantic ruins, studied geology, and picked up information from the folk he met. Fine scenery was always his delight, and he would sometimes rave about it. 'But,' says one of his companions, 'even his nonsense was that of a superior being.'

We are now at that prolific period of Davy's life when hardly a week passed without his making some discovery. Of these, he neglected the smaller fry, and published the more important. We shall only give an account of the leading chain.

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[1] By Bartley, Jan. 30, 1805.

His note-books at Clifton, in 1799, show that his thoughts were already turned towards the great work of his life. Amid the mass of jottings for essays, minutes of experiments, titles for poems and romances, and fragments of verse or tales which fill them, we find this prophetic entry, 'The first step towards these laws (of corpuscular or atomic motion) will be the decomposition of those bodies which are at present undecomposed.' The bodies referred to were the fluoric, muriatic, and boracic acids, as well as the alkalis and earths. Thus early he had tried to decompose muriatic acid by passing the electric spark through it, but without success. The pile of Volta, however, furnished a better means, and the decomposition of water by its current, accidentally observed by Carlisle and Nicholson, on April 30th, 1800, became his starting-point into the promised land. He verified this observation, and followed it up by a series of experiments which culminated in his Bakerian lecture on 'Some Chemical Agencies of Electricity,' delivered to the Royal Society on November 20th, 1806. Volta himself had noticed that when water is decomposed in this way into its constituent gases, oxygen and hydrogen, an acid always appeared at the electrode or wire connected to the 'positive' pole of the battery, and an alkali at that joined to the 'negative' pole. Some thought the acid was nitrous or muriatic, and that the alkali was ammonia. Others called the acid *electric*, and held that it was generated by the union of electricity with the water. Davy set himself to clear up this confusion. Taking two glass tubes containing distilled water, he connected the liquids by a strip of moist bladder, and sent the current from a battery through them both by gold electrodes dipping into them. Oxygen gas appeared at the positive pole and with it nitro-muriate of gold, while hydrogen gas appeared at the negative pole, and with it soda. Davy regarded the pure gases as the only constituents of water, and the other products as the effect of impurities. He attributed the muriatic acid to the bladder, and the soda to the glass tubes. So he replaced the former by a thread of purified asbestos, and the latter by two cups of agate. But he still found traces of the acid and the alkali. Repeating the experiment with greater care, he succeeded in diminishing the quantity of acid, but not that of the alkali. Thinking the agate might contain a salt his chemical tests could not reveal, he discarded it for two cups of gold, but the acid came as strong as ever, and the alkali was only checked. Suspecting the water, he evaporated it in a silver dish, and found a residue of saline matter. Having doubly distilled it he obtained a mere taint of alkali, and that not fixed, but volatile. It then occurred to him that the nitrous acid and ammonia might be formed by the nascent oxygen and hydrogen combining with the air dissolved in the water. He therefore made the experiment under a bell jar exhausted by an air-pump, and got no alkali, but still a tincture of acid. Not satisfied with a vacuum which at best is only partial, he displaced the air in the bell jar by pure hydrogen, and then found neither acid nor alkali. He had proved that water is decomposed by electricity into hydrogen and oxygen.

Encouraged by this achievement, and having noticed the solvent action of electricity on glass, Davy next attempted to decompose the earths. His results were published in his second famous Bakerian lecture, delivered on November 19th, 1807, and entitled: 'On some new Phenomena of Chemical Change produced by Electricity, particularly the decomposition of the fixed alkalis; and the exhibition of the new substances which constitute their bases; and on the general nature of all alkaline bodies.'

He began with the solid earths, and followed the same method as before. His cups were formed of the substance to be decomposed, and contained pure water, connected through asbestos, which being a porous mineral, absorbed the water, and completed the circuit of the battery. With cups of gypsum, or sulphate of lime, he found lime at the negative pole and sulphuric acid at the positive. In the same way he reduced a variety of earths, such as the sulphates of strontia and baryta, basalt and zeolite, from the Giant's Causeway, and lava from Mount Etna. He then turned to the soluble salts, using agate cups with platinum wires, and decomposed a number, finding the acid always at the positive pole, and the alkaline base at the negative. In some, crystals of the pure metal, as well as its oxide, appeared at the negative electrode. The results implied that matter was transferred from one cup to the other through the asbestos by a process of decomposition and recomposition. He proved this by interposing ammonia, and arresting the acid in its passage. Further, he inferred that hydrogen, metals, and the alkalis, being always attracted to the negative pole, were themselves positive, while oxygen and acids were, on the contrary, negative electric bodies. Moreover, he concluded that the electric force required to disunite the constituents of a compound was a measure of their chemical affinity, and thus founded the modern science of electro-chemistry.

A new horizon was opened up by this discovery. Davy himself had glimpses of its future importance, for we find him shrewdly speculating on the effects of terrestrial electricity on the chemical changes of the earth's mass and the animal economy. Having observed that the intensity of the electric current increases with the number and size of the plates in the battery, he hoped by constructing a powerful one to decompose such bodies as potash and soda, which were regarded as simple. With solutions of these salts he only generated heat and ebullition; with melted potash in a tube he is thought to have reduced the metal without recognising it; but on laying a piece of potash on a platinum disc connected to the negative pole of the battery, and touching it with a platinum wire attached to the positive pole, he obtained a violent effervescence at the wire, the potash began to fuse, while globules resembling quicksilver appeared on the disc and burst into flame. Davy was intensely excited at this discovery. He could not contain his joy, says a biographer, he actually bounded about the room in ecstatic delight, as though he had taken laughing-gas, and some little time was required for him to compose himself sufficiently to continue the experiment.

He identified the globules as the new-found metal 'potassium,' and the gas at the positive pole as oxygen, thus proving that potash was an oxide. Potassium had several peculiar properties. Owing to its strong affinity for oxygen, it burnt in the air or water, and even on a piece of ice, with a vehement and rosy flame. It was therefore necessary to keep it in a liquid which contains no oxygen, for instance, naphtha. Unlike other metals, it was so light as to float in water; but such is the influence of imagination that a caller at the laboratory, on being asked what kind of stuff it was, replied, 'Why, metallic, to be sure' (and after poising it on his finger): 'Bless me, how heavy it is!'

Soda was decomposed soon afterwards; and Davy, in the heat of the moment, sat down and dashed off his lecture. In his scientific memoirs he of course avoided the ornaments of his popular style, regarding them as wild flowers in a field of corn, pretty to look at, but cumbering the grain.

This feverish activity was followed by a severe illness, during which he lay for five weeks at the door of death. He believed it to be the 'jail' fever, caught in fumigating a prison; but his physician said it was due to overwork. Davy was inclined to burn the candle at both ends. After a hard day in the laboratory, he would hastily dress himself and go out to dine, returning later to continue his experiments, until three or four in the morning. To save time, he would don a clean shirt over the soiled one, and sometimes had five on at once, with as many pairs of stockings. Indeed, his friends were often alarmed at the cyclic changes of his bulk.

During the illness, which was aggravated with delirium, he took strange longings for his old home and relatives in Penzance. He sighed for a particular teapot, endeared to him by early associations, and was quite impatient until he got some apples from a tree he had planted as a boy.

He had discovered potassium and sodium in October, and was taken ill in November, 1807; but it was the following March ere he resumed his lectures at the Royal Institution. In the meantime his discovery was making headway; but it met with doubts and opposition. At this time Lavoisier was the great authority on chemistry, and Lavoisier had said that oxygen was the acid-maker. How, then, should oxygen when combined with a metal produce an alkali? Men do not readily give up their cherished ideas even in science, and the truth was reluctantly admitted. A certain Aberdonian professor, who ignored it as long as possible, had at length to bring it to the notice of his class. 'Potash and soda are now said to be metallic oxides,' he remarked, 'the oxides, in fact, of two metals called potassium and sodium by the discoverer of them—one Davy in London—a vera troublesome person in chemistry.'

On recovering his health Davy continued his researches, and decomposed other metallic oxides, such as strontia, baryta, and lime. The Royal Institution provided the most powerful battery then known, consisting of 200 porcelain cells, each containing ten double plates. Armed with this, he attacked a number of substances, such as charcoal, sulphur, and the acids, muriatic, fluoric, and boracic, decomposing some of them, and discovering new elements, such as boron, but failing in others, for example, sulphur. He was quick at forming theories, and ready to abandon them when they did not stand the test of experiment.

With the same powerful battery he discovered the electric light. On attaching two pencils of charcoal to the wires from its poles, and bringing them together, then drawing them apart, a brilliant 'arc' of light was seen crossing the gap. The points of the sticks became white-hot; platinum melted in the blaze, and ran like wax; refractory minerals such as sapphire, quartz, and magnesia were fused, and bits of diamond seemed to evaporate. The light could also be produced under insulating oils and ether.

Long before this he had rendered slips of platinum incandescent by sending the current through them, as Professor Tromsdorf had done with gold and silver foil.[1] From a letter to Mr. Children, dated September 23, 1809, we also find that he was attempting to decompose dry muriatic acid gas by means of

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Dr. Paris, *Life of Humphry Davy:* letter to Davies
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charcoal kept at a white-heat by the electric current; and in the same letter he remarks, 'I find the radiation *in vacuo* from ignited (*i.e.* incandescent) platina is to that in air as three to one.'

These results were communicated to the Royal Society in his Bakerian lectures for 1808 and 1809. He was now a secretary of that body; and, despite the animosity existing between France and Great Britain at the time, the French Institute magnanimously awarded him the gold medal of the First Consul, valued at 3000 francs. Narrow spirits advised him to decline the honour, but Davy took a better view, and accepted it. 'If the two countries or governments are at war,' said he, 'we men of science are not. . . . We should rather soften the asperity of national hostility.'

Davy was now led to investigate the constitution of muriatic, or as it is now called, hydrochloric acid. The yellow gas given off by this acid had been discovered by Scheele, and was known as oxydised or oxy-muriatic acid. According to the reigning theory of Lavoisier, muriatic acid must contain oxygen, since that was the acidifier. Davy showed, however, that dry oxy-muriatic acid gas was unaffected by incandescent charcoal, and contained no oxygen. He proved it to contain an element which, owing to its yellow colour, he renominated *chlorine* (from the Greek, *chloros*, yellow); and demonstrated that muriatic acid contained no oxygen, but was simply a compound of chlorine and hydrogen. Chlorine, in short, was found to be an 'acidifier' as well as oxygen.

Lavoisier taught that an *acid* was the oxide of a non-metal; and a *salt* the compound of an acid with a *base* or oxide of a metal. Davy showed that an acid was not necessarily an oxide, since it might consist of hydrogen and chlorine, and that a salt consisted of an acid in which the hydrogen was replaced by a metal.

This was a trying investigation, for, as Davy remarks, 'it is more difficult to overcome an old error than to find a new truth; the mind in the first case being fettered, and in the last free.' As usual, the new discovery was questioned, and after its acceptance attempts were made to transfer it to others. Berzelius was one of the last to adopt the novel theory; and Wöhler relates that when he was a pupil in the laboratory of the great chemist at Stockholm, Anna, the old cook, while washing some basins happened to say that they smelt strongly of oxydised muriatic acid. 'Now, listen to me, Anna,' said Berzelius. 'Thou must not longer say, "oxydised muriatic acid," but "chlorine;" that is better.'

These last results of Davy, which effected a revolution in chemistry, were communicated to the Royal Society in the Bakerian lecture for 1810. Although he was only thirty-two years of age, he was now at the zenith of his fame, admired for his energy and talents, esteemed for his virtues, and loved for himself. He had entered his name at Cambridge for the purpose of studying medicine, but afterwards gave up his intention. Nor did he enter the Church, although invited to do so, but continued faithful to his vocation. 'Science is valuable for many reasons,' he wrote; 'but there is nothing that gives it so high and dignified a character as the means which it affords of interpreting the works of Nature, so as to unfold the wisdom and glory of the Creator.'

In 1810, he met his future wife in Mrs. Apreece, a widow of rank and fortune, amiable, accomplished, and of similar tastes to his own. Davy believed that if he had not known her, he would have remained a bachelor. They were married on April 11th, 1812, and on the eve of the ceremony, Davy was knighted by the Prince Regent during a levee at Carlton House. He was proud of the honour, he said, because it had been borne by Newton. Prior to this, he had been distinguished by the academic degrees of LL.D. and D.C.L. His honeymoon was spent in Scotland, of which country his wife was a native, and where he was able to enjoy his favourite pastimes of shooting grouse and fishing for salmon.

Soon after this he published his *Elements of Chemistry*, which was written during his courtship, and became connected with a gunpowder factory as scientific adviser. But he declined all share in the profits, as he had always kept aloof from the commercial side of science, being of opinion that, as Lord Bacon writes, 'the applying of knowledge to lucre diverts the advancement of knowledge, as the golden ball thrown before Atalanta, which, while she stoops to take up, the race is hindered.' In 1813, he published his *Elements of Agricultural Chemistry*, and in October of that year he paid a visit to the Continent with his wife. The emperor had permitted them to travel through France, and after a temporary detention, through an official blunder, they arrived in Paris, where they met with a flattering reception, and saw all the places of interest. Dr. Paris intimates that Davy did not create a favourable impression in the capital. Whether he was blinded by a national prejudice, or the pursuit of science had dulled his appreciation of the fine arts, he remained cold and indifferent to the treasures of the Louvre. When Raphael's 'Transfiguration' was pointed out as the masterpiece of the collection, he merely observed, 'Indeed; I'm glad I've seen it;' and when he saw the alabaster statue of Antinous, he exclaimed, 'What a beautiful stalactite!' Such conduct looks like the affectation of indifference. He was introduced to the first society of the capital, and met a great many illustrious men, including Humboldt and Gay-Lussac, Count Rumford, then living at Auteuil, Ampère, his friend and correspondent, Dulong, Cuvier, Chevreul, the chemist, who was then a young man and a brother of the angle. It was in Chevreul's laboratory, at the Jardin des Plantes, that Davy investigated the properties of iodine, a new element in the form of black crystals with a violet vapour, which was brought to him by Ampère, and proved it to be another 'acidifier,' like chlorine and oxygen. Davy and his wife were presented to the empress at Malmaison, but not to the emperor. He had not attended the levée, and Napoleon never sent for him. In seeking a cause for this apparent slight, Dr. Paris mentions a story which was current at the time. It appears that the emperor had ordered the Institute to procure a powerful battery, and when he went to see it, had recklessly thrust the wires into his mouth to 'taste' the current by the Sulzer effect, and received a shock which nearly knocked him senseless. On recovering from it, he quitted the place without remark, and never afterwards alluded to the subject. It was thought that he had conceived a dislike to electricity and its professors from this untoward incident; but it is more probable that if the emperor willingly overlooked the distinguished visitor, it was rather owing to the name for haughtiness which Davy had acquired, for it had come to his ears 'that the young English chemist held them all in low estimation.' If this were so, the compliment was returned by a political personage, who, on seeing Davy at a reception, and ing told that he had created a 'revolution in nistry,' curtly replied, 'I hate all revolutionists.'

Dr. Paris thinks that Davy's flippant manner was assumed to conceal an awkward timidity. Perhaps, however, the rumours of his ill-breeding have been exaggerated. Some allowance should be made for his youth and the intoxication of success. Be this as it may, he was elected a Corresponding Member of the Institute.

Davy travelled into Italy by way of Montpelier, and visited Rome, Naples, Pompeii, and other cities, not forgetting Pavia, where he paid his court to Volta. The Italian dressed himself in state to receive the illustrious foreigner, but he was taken quite aback when Davy entered the room in a travelling suit 'of which an English artizan would have been ashamed.'[1] From Italy he passed into Switzerland, where at Geneva he made the acquaintance of De Saussure, Pictet, Necker, Benjamin Constant, Talma the actor, and Madame de Staël. From Switzerland he travelled through Germany to Ostend, and thence to London, where he arrived in April 1815.

During these two years he had not been altogether idle. Besides his investigation of iodine at Paris, he had made experiments on the torpedo, and the combustion of the diamond in the focus of a powerful lens, the composition of the colours in Pompeiian frescoes, and of the fire-damp of the Pietra Mala, which he proved to be a light carburetted hydrogen. The latter research was a foretaste of his next important work, the invention of the miner's lamp. While Davy was travelling alone in Scotland, during the autumn of 1815, some dreadful explosions took place in the collieries of Durham and Northumberland, and he was invited to invent a safety lamp by a new society established to prevent such accidents. Davy went to Newcastle, procured specimens of fire-damp, analysed their properties, and in less than a fortnight had invented four kinds of lamp. But it was not until June 1816, that he arrived at the model with the wire-gauze covering which bears his name. In the course of his experiments, which were communicated to the Royal Society in 1817, he found that fire-damp impinging upon platinum could make it glow with heat. The Davy lamp has been of inestimable benefit to the miner in saving life and property. Davy was urged to patent it and draw his £5000 or £10,000 a year of royalty for its use; but he resolutely declined, and gave it freely to the world. His sole object in inventing it was to serve humanity; 'he had wealth enough.'

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[1] Dr. Paris. If this be true, we can only say it must have been a very bad suit indeed. But perhaps Dr. Paris makes too much of these trivialities.

He was presented with an address of thanks and a service of plate by the coal-owners of the North. The Government, which gave Sir William Congreve a pension of £1200 a year for his destructive rocket, had no recompense for the safety lamp. Nevertheless, Davy was created a baronet on October 20th, 1818.

He returned to Italy in the summer of this year, and tried to render the papyri of Herculaneum legible; but without success. After that he travelled in Germany, Hungary, and elsewhere, returning home in 1820. During his voyage he had done some minor work, having proved the night mists of a river to be caused by the greater warmth of the water as compared with the land. On November 30th, 1820, he was elected President of the Royal Society, vacant by the death of his friend, Sir Joseph Banks. The following autumn he paid a visit to his mother at Penzance, where he was entertained at a public dinner, and subsequently enjoyed another holiday in the Highlands.

Oersted's discovery of the connection between electricity and magnetism next engaged his attention, and he performed a variety of experiments on the subject, which were described in papers to the Royal Society. One of his deductions was that terrestrial magnetism might be due to electric currents circulating in the mass of the earth; and another that the *aurora borealis* was perhaps due to an electrical discharge. On December 20th, 1821, he read a memoir to the Royal Society 'On the electrical phenomena exhibited *in vacuo*,' which tended to show that electrical effects depended on the presence of an ethereal fluid. After his assistant, Michael Faraday, had liquefied chlorine gas, Davy condensed several others by confining them in a closed vessel and producing the requisite pressure by the application of heat. His next investigation was on the application of zinc to preserve the copper sheathing used to protect ships' bottoms; and in this connection he made a voyage to Scandinavia on Her Majesty's ship Comet, which was placed at his disposal by the Admiralty. Among the magnificent scenery of Norway, he was able to pursue his favourite sport of salmon fishing; and in Sweden he met with Berzelius by accident. At Copenhagen he renewed his acquaintance with Prince Christian, afterwards King of Denmark, and had the pleasure of meeting Oersted. At Bremen, on his way home, he encountered Professor Gauss, of Göttingen, who was then surveying in Hanover. He returned to England in August, but his experiments on sheathing turned out a partial failure, much to his vexation. They formed the subject of his last Bakerian lecture, delivered to the Royal Society on June 8th, 1826.

4 8 7

Davy's health now began to decline, and he looked about for a quiet country residence, a day's journey from London, with the sea before it, and a river running through it. Towards the end of the year he was seized with apoplexy while returning to London from a visit to Lord Sage. Copious bleeding saved him; but his gait was partially paralysed. Being ordered to Italy for the rest of the winter, he chose Ravenna, for its retirement and historical associations. He was put on strict regimen, forbidden to experiment, but allowed to ride about the pine forests. Next year he travelled in Illyria with his brother, Dr. Davy, and returned to England in the autumn. He had resigned the presidency of the Royal Society, owing to his illness. His friend Mr. Poole relates that when Davy came to visit him at Stowey, and entered the private laboratory there, 'he threw a glance around, his eye brightened, his face glowed, and he looked twenty years younger.' Davy told his friend that he did not wish to live for his own sake, but that he had views which might be useful to his fellow-men. Although he took daily exercise, and even rode to cover, he was afflicted by a sense of powerlessness. In December he returned to London, and on the following March he communicated a paper to the Royal Society on 'Volcanoes,' which proved to be his last. He again wintered in Rome, 'a ruin amongst ruins,' as he described himself; 'a pendulum swinging between life and death.' In the spring he published his *Salmonia, or Days of Fly Fishing*, which, like his final work, *The Consolations of Travel, or the Last Days of a Philosopher*, was written to beguile the tedium of his confinement. They are poetico-philosophical works, written in dialogue, on the model of Isaac Walton's *Complete Angler*, and characterised by a devout spirit, a penetrating intellect, and a poetical imagination. Part of the latter was dictated in the intervals of his last attacks, when he had lost the power of writing.

From Rome he was conveyed to Geneva, at his express wish, by his wife and Dr. Davy. They arrived at the Hotel de la Couronne on the 28th of May. At 4 P.M. they dined, and Davy appeared unusually cheerful. At 11 P.M. he drank a dish of tea, and retired to rest at midnight. Soon afterwards Davy summoned the manservant, who slept in his room, and desired him to call his brother. When the latter entered the room Davy said that he was dying, but wished no one in the house to be disturbed until after it was all over. He expired without a struggle, about a quarter to three in the morning of May 29th, 1829. Davy was buried in the cemetery of Plain-Palais, without the walls. The funeral was public, and attended by the magistrates and professors of the town.

During his fatal illness Davy reverted often to his earliest impressions, and became almost a boy again. When his will was opened, it was found that he had bequeathed £100 to give an annual holiday to the pupils of Penzance School on his birthday. Having left no children, the baronetcy ended with him. His widow placed a tablet to his memory in Westminster Abbey, and his townsmen erected a statue in his honour beside the town hall of Penzance.

In person Davy was middle-sized, and of good features. His eye was bright and penetrating; his brow high and broad, and shaded by waving locks; his mouth well turned, and at once firm and sensitive. He possessed most of the merits and foibles which are vulgarly associated with genius, not omitting a certain irritability, and a tendency to superstition. For example, he never liked to see a knife and fork lying crossed upon a plate. Mr. Knight, of Downton, who saw a good deal of him, considered that he was 'a more *extraordinary* being' than his writings or discoveries evinced, and says that 'in the extent of his intellectual powers I shall ever think that he lived and died without an equal.' As an experimenter Davy hunted down the truth, step by step, until he had captured it in its lair. As a prose writer, many of his sentences are worthy of preservation. We shall conclude with a few short specimens:—

'Great powers have never been exerted independently of strong feelings.'

'No man ever had genius who did not aim to execute more than he was able.'

'Nature and domestic attachments are the true sources of happiness. Cosmopolitanism, the love of notoriety, not fame, the love of pleasure, are all fatal to the first and strongest feelings of our nature.'

'One use of physical science is that it gives definite ideas.'

'Experiments, even apparently the most trifling, can hardly fail to be useful.'

'The grandest as well as the most correct views are those which have been gained by minute observation, and by the application of all the more precise and accurate methods of science.'

'Theories ought to be made for a time, and be considered capable of improvement.'

'Experimental science hardly ever affords us more than approximations to truth, and whenever many agents are concerned we are in great danger of being mistaken.'

In *Salmonia* he writes: 'I envy not qualities of the mind or intellect in others, be it genius, power, wit, or fancy; but if I could choose what would be most delightful, and I believe most useful to me, I should prefer a firm religious belief to any other blessing; for it makes life a discipline of goodness; ites new hopes when all earthly hopes vanish, and throws over the decay and destruction of existence the most gorgeous of all lights.'

In the *Consolations of Travel* we find the following passage: 'Behold me on the couch of death, my senses lost, my organs falling towards that state in which they will be resolved into their primitive atoms; still is my mind unconquered, still all my passions, all my energies are alive; still are all my trains of thinking complete. Philosophy has warmed me through life; on the bed of death she does not desert her disciple. The frost of the grave can never chill those burning energies connected with the thoughts of future existence. I feel and believe that the general warmth of the sun of immortality which has shone through this shattered frame with feeble light shall be more permanent in the region of bliss.'

A complete edition of his works, edited by his brother, Dr. John Davy, was published in 1839.

HANS CHRISTIAN OERSTED.

HANS CHRISTIAN OERSTED.

In the galaxy of lights which illuminated the north of Europe at the dawn of the present century a magnificent cluster appeared in Denmark, when Oehlenschläger represented literature, Thorwaldsen art, and Oersted physics. Oehlenschläger is the Walter Scott of his native country, Thorwaldsen the Phidias of Scandinavia, and the most famous sculptor of modern times, while to Oersted we owe one of the most prolific discoveries which have ever been made, namely, the connection between electricity and magnetism. Volta, indeed, had given us in the chemical pile a new source of electricity, which in the hands of others became a potent engine of research; but it was not until the discovery of Oersted that the great practical developments of electricity took their rise, and culminated in the telephone, the electric light, and the transmission of motive power.

Hans Christian Örsted, or Oersted, was born in the little Danish town of Rudkjoking, in the island of Langeland, on the 14th of August, 1777. His father, the village apothecary, had probably enough learning to appreciate the value of education, but was too poor to give his children the advantage of it Indeed, there seems to have been no school in the town; and the parents, with a large family on their hands, kept the two elder boys out of mischief by sending them every day to an old German wigmaker and his Danish wife, who lived near by, in humble but honest circumstances. Anders Sandoe Oersted, who afterwards became the most eminent jurist in Denmark, was younger than Hans by a year. They were both eager for instruction, and Christian Oldenburg, the wigmaker, taught them German, while his good wife taught them to read their native tongue. The parents, too, when their boys were at home, sought to develop their faculties by conversation, and the lads themselves hit upon the plan of imparting their ideas and information to one another; and their progress was so rapid that their younger brothers and sisters were put to the same academy, which became so popular in Rudkjoking that the old wigmaker, as his trade of embellishing the exterior of the head went out of fashion, forsook it for the equally honourable one of furnishing the inside. An important part of his curriculum consisted in reading a passage out of the German Bible, and hearing the senior pupils translate it literally into Danish. His wife also made the children commit the Commentaries of Pontoppidan to heart with the greatest accuracy. Writing was taught from copy-book slips, procured from Lübeck, and arithmetic by means of an old German treatise. The pedagogue's acquirements were limited to addition and subtraction; but another boy, who had once been at a better school, showed them how to multiply, and a pastor who frequented their father's house taught them to divide. The rule of three Hans mastered for himself, by the help of an old arithmetic which he found amongst his father's books, and then explained it to his brother. Beside their lessons at the wigmaker's, when seven or eight years old, they had some daily lessons in Latin, and translated a German history of the world. Intending to be ministers, they applied themselves to writing sermons, an art in which Anders excelled. Hans, indeed, was more inclined towards poetry, and began to learn drawing under the tuition of a baker who had travelled a great deal and seen the world.

The boys, in fact, took every opportunity they could get of learning something, and after their father put them both into his shop, having no other assistant, their zeal for self-improvement never abated. They managed to secure several hours of academic instruction from a university student who gained his living partly by teaching, partly by preaching, and also by engraving signet-rings. The mayor of the town was kind enough to teach them French and English. They borrowed every book they could get in the village, and bought others with their frugal savings. Their thirst for knowledge was no less remarkable than their mutual helpfulness. Whatever knowledge one had acquired was communicated to the other, so that their education went on in common.

Hans was twelve years old when he entered his father's shop, and their education, till then very general, began to take a special turn. Anders evinced a growing taste for law, and Hans, while fostering his imagination on books of poetry, romance, and history, also manifested, like Humphry Davy, an interest in medicine and science.

In the autumn of 1793, the brothers resolved to become students at the University of Copenhagen, and the following spring, with the consent of their father, they proceeded to the capital in order to have the benefit of six months' preliminary training before the winter classes opened. They passed the entrance examination with the highest marks, and here their mental paths diverged; Anders plunging into the study of law and philosophy, while Hans devoted himself to medicine, astronomy, and physics. During the six years of their student life they had but one purse between them, and still continued their practice of aiding one another in their studies. They lodged together at the college, dined together at the house of an aunt, and though at first obliged to live very sparingly, they succeeded with a little government assistance, and by giving private lessons, in maintaining themselves without help from their father, who had other mouths to feed. Students, as a rule, enjoy the intoxication of youth with uncommon zest; but the brothers Oersted found all their delight in quiet, earnest work, and intellectual conversation. Oehlenschläger, though a striking contrast by his excitability and pride of life, was almost their only friend. His sister afterwards became the wife of Anders, and he himself remained a life-long friend. In his essay on the *School in Life*, Oersted exclaims, 'Resist the insidious seductions which would tempt you to sacrifice your youth to the occupations of manhood! You thence overleap a period of life rich in joys, and still richer in seeds for a more important future. Be persuaded that he only who has been a genuine youth, in the actual sense of the word, will afterwards become a genuine, many-sided, and well-cultivated man, and at the conclusion of his path be a truly wise old man. . . . Every period of life has its essential signification in the life of man; something peculiar happens in each to further the development of mankind, and that which is contributed by one age cannot be perfectly supplied by any other.' That Oersted did not believe he had mis-spent his own youth may be gathered from a later passage in the same address, in which he says, 'It is unnecessary to overleap the short period of youth. While he is making his preparation, the world does not pass so rapidly that he will lose the opportunity of performing a great action, if he has the requisite ability. To be perfectly free, the young man must revel in the great kingdom of thought and imagination; there is a struggle there, in which, if he falls, it is easy for him to rise again, there is freedom of utterance there, which draws after it no irreparable consequences on society, and therefore imposes neither that outward nor inward responsibility which disturbs the soul and enfeebles its cheerful elasticity. It is with pleasure that I recur to that happy existence, when I lived in this onward-striving contest, where each day overcame a new difficulty, gained a new truth, or banished a previous error. That I had not yet entered into the business of the state threw no cloud over this world of light. It did not occur to me to doubt that an efficient cultivation of my faculties would certainly afterwards obtain for me a suitable place in society. The history of my youth is not essentially different from that of many others who have had the happiness not to deviate from the path appointed to them by Nature.'[1]

They were stirring times when Oersted was a student. In France the Revolution had opened a new era, in Germany a fresh poetical and philosophic gospel had been proclaimed. Oersted felt the stimulus of his age, and became attached to the new æsthetic movement in the North. In 1797, when he was twenty, he gained the University prize, a gold medal, for an essay on the *Limits of Poetry and Prose*, About the same time he passed his pharmaceutical examination. The following year he gained another prize for an essay on a medical subject, and in 1799 he took his degree of Ph. D. (Doctor of Philosophy) with a dissertation on the 'Architectonicks of Natural Metaphysics.' In a criticism of Gadolin's *Introduction to Chemistry*, he promulgated a new theory of alkalis, which was afterwards adopted.

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[1] *The Soul in Nature*, translated from the German by L. & J. B. Horner.

In 1800, having finished his university course, he undertook the charge of an apothecary's shop in Copenhagen, and delivered extra lectures on chemistry to the medical students at the university. Volta's discovery of the pile called up a number of experimenters, and led Oersted to make some new observations on the production of acids and alkalis by the current. Next year he set out on his travels, visiting Germany, France, and the Netherlands. He became acquainted with some of the leading thinkers in Germany, amongst them Schelling, Rumford, the brothers Schlegel, Fichte, and Tieck. Ritter, the physicist, was, however, his most intimate acquaintance, and in the winter of 1802–3 he translated Ritter's account of his new 'pile' for the French Institute, and led its author to declare that he understood the translation better than his original. He also introduced the *Prolusiones* of the Hungarian chemist Winterl to the German scientific world. Wherever he went the depth of his learning and the activity of his mind astonished those who came in contact with him, and the youthful freshness of his childlike manners won their hearts.

On returning to Copenhagen in 1803, by Brussels, Leyden, Haarlem, and Amsterdam, he applied for the chair of physics in the university, but failed, owing perhaps, to his being regarded as more of a philosophic thinker than a physicist. For three years, however, he received an income of 300 bank thalers from the public purse, and an equal sum to make experiments. The laboratory of the university had been destroyed by fire; but Oersted received a private set of apparatus, and delivered lectures on natural philosophy in the light of the dynamical theory. At the same time he published a variety of papers written in German and Danish. These labours proved stepping-stones to the chair of physics, which he obtained in 1806. The sphere of his operations was now widened, and his activity increased. He delivered numerous public and private lectures, became a teacher at the Academy of Land Cadets, extended his collection of apparatus, and published in 1809 his *Manual of Mechanical Physics.* Though fairly embarked on a scientific career, he kept up his interest in the literary and social movements of the time. Denmark is a small country, with a single university; and when a man becomes famous, he is free to move in the highest circle, among the most distinguished of his age. Oersted enjoyed the best society of the capital, and maintained an intercourse with his fellow-student Oehlenschläger, with Steffens, the critic, Lehman, the orator, Mynster, Bishop of Seeland, and the witty poet Baggesen.

In the years 1812 and 1813 he travelled again in Germany and France. While at Berlin he published, by the advice of Niebuhr, his *Views of the Chemical Laws of Nature,* subsequently translated in Paris and published under the title of *Recherches sur l'identité des forces Electriques et Chimiques,* a work which laid the foundation of the electro-chemical system afterwards developed by Berzelius. In this work he hints at the necessity of trying whether galvanic electricity will not affect the magnetic needle.

On returning home he married, in 1814, an excellent woman who had been a housekeeper, and survived him twenty-five years. By her he had three sons and four daughters, none of whom made any mark, if we except his daughter Mathilde, who collected and published her father's letters. 'His house,' says a writer, 'was a home of peace and love, where his seven children gathered round their parents. He was very fond of joy and happiness, but when the sorrow came bore it with great patience.'

In the same year he engaged in a literary duel with Grundtwig, in which he advocated freedom of judgment as opposed to dogma. He also published a series of hints in favour of a national terminology of science, emancipated from the Greek and French influences which then prevailed. In a speech made at a festival he declared the practice of science to be an act of religious worship.

For some years after this he was busily engaged in lecturing, sometimes for five hours daily. Besides his college classes he lectured in German to the diplomatic corps. Nevertheless, he found time to devise an improved voltaic cell, and a fuse for igniting gunpowder by a fine wire made red-hot by the passage of an electric current. In 1818 to 1819, by command of the King of Denmark, he undertook, along with Forchhammer, the geologist, a scientific survey of the island of Bornholm, till then neglected, and found it well stocked with coal and ironstone.

It had long been surmised that electricity and magnetism were connected. Lightning was known to magnetise iron, and affect a compass needle. Beccaria and Von Marum had magnetised iron by sending an electric current through it. But no one had discovered the true nature of the connection. Oersted, like others, had mused upon the problem, and tried to solve it, but never in the proper way. It is said that he always put the wire conveying the current across the needle of a compass instead of parallel to it. There is a want of clearness in the narratives of his discovery, which was made at a private lecture to advanced students in the winter of 1819. According to one, he chanced to put the wire parallel to the needle; and according to another, he was showing the phenomenon of a fine platinum wire heated to a glow by the passage of a current through it; and happening to lay a small compass underneath, he observed the needle swing aside, as though it were influenced by another magnet. Struck with the effect, Oersted investigated the matter later on, and, by the help of a more powerful battery and larger wires, he succeeded in turning the first feeble impulse into a strong and unmistakable deflection. He defined the conditions of the experiment, and on July 21st, 1820, posted to the learned societies a Latin tract, entitled *Experimenta circa effectum conflictus electrici in acum magneticam*, giving an account of his discovery, and showing that a current flowing in a wire produces a magnetic effect in a circular direction round about the wire. In short, he had proved that an electric current gives rise to what is called a circular magnetic field around the conductor through which it is passing, so that if a magnetic needle is brought near the conductor it will tend to set itself at a tangent to the circular field around it; that is to say, at right angles to the direction of the current. One of the poles, if it were free, would tend to circulate round the conductor in one direction, and the other pole in the opposite direction. It followed that on reversing the direction of the current through the conductor the direction of motion of the poles would also be reversed.

Such was the discovery of Oersted, which founded the new department of 'electro-magnetism.' Some say it was a lucky accident; but 'accidents' like this are but the windfalls of the investigator, who alone discerns their true significance. Any one can pick up a clear pebble and throw it away, but it is only the skilful seeker who can recognise the diamond. Besides, we do not know all that passed in Oersted's mind when the happy thought occurred to him.

The original compass has been preserved, and was exhibited at the Vienna International Exhibition of

Electricity in 1883; but of the many thousands of visitors who gazed and wondered at the bewildering variety of apparatus displayed around them, probably there were few who marked the humble little needle from which these were derived.

The year 1820 was, according to his own testimony, the happiest in Oersted's life. Honours and congratulations flowed in upon him after his discovery was verified, and many learned societies elected him a member. The Royal Society of London awarded him the Copley Medal, and the Institute of France presented him with a prize of 3000 francs.

Although this great achievement has put his other work in the shade, it should not be forgotten that Oersted did many other services to science. He invented the piesometer, for measuring the compressibility of liquids, introduced a new method of making chlorides out of oxides, and discovered the metal aluminium.

In 1822-3, with the assistance of the Danish Government, he travelled again in Germany, France, and England, and brought back a number of new instruments. He founded a society for the diffusion of natural science in Denmark the following year, and lectures on science were delivered under its auspices in all the principal towns. In 1823-4 he delivered a course of French lectures; and in 1828 he went to Norway and to Berlin, where he gave an address to the Society of Naturalists. In 1830 he delivered another to the same body in Hamburg; and four years later he visited the celebrated Gauss at Göttingen, in order to study his observations in magnetism, with the view of establishing a magnetic observatory in Copenhagen. He took an active part in the meetings of the Scandinavian naturalists, which, after 1839, were held in one or other of the northern kingdoms.

In 1836 he visited France and England, and was present at the Southampton meeting of the British Association. On that occasion Sir John Herschel said, that 'in science there was but one direction which the needle would take, when pointed towards the European continent, and that was towards his esteemed friend, Professor Oersted. He knew not how to speak of him in his presence without violating some of that sanctity by which, as an individual, he was surrounded. To look at his calm manner, who would think that he wielded such an intense power, capable of altering the whole state of science, and almost convulsing the knowledge of the world? He had at this meeting developed some of those recondite and remarkable powers which he had been himself the first to discover, and which went almost to the extent of obliging them to alter their views on the most ordinary laws of force and motion. He elaborated his ideas with slowness and certainty, bringing them forward only after a long lapse of time. How often did he (Sir John Herschel) wish to heaven that he could trample down, and strike for ever to the earth, the hasty generalisation which marked the present age, and bring up another and a more safe system of investigation, such as that which marked the inquiries of his friend! It was in the deep recesses, as it were, of a cell, that, in the midst of his study, a dim idea first struck upon the mind of Oersted. He waited calmly and long for the dawn which at length opened upon him, altering the whole relations of science and, he might say, of life, until they knew not where he would lead them to. The electric telegraph, and other wonders of modern science, were but mere effervescences from the surface of this deep recondite discovery which Oersted had liberated, and which was yet to burst with all its mighty force upon the world. If we were to characterise by any figure the advantage of Oersted to science, he would regard him as a fertilising shower descending from heaven, which brought forth a new crop, delightful to the eye and pleasing to the heart.'

During his visits to England he made the acquaintance of many eminent men, amongst them Wollaston and Sir Humphry Davy, Faraday, and Sir Roderick Murchison. In Germany, too, he met the illustrious Goethe, and frequently corresponded with him.

As he grew in renown Oersted's worldly position improved still more. He became Secretary to the Royal Society of Sciences in Copenhagen, Professor Ordinarius at the University, a Corresponding Member of the Academy of Sciences in Paris, and Director of the Polytechnic School, which had been founded in 1829, through his influence with King Frederick VI. In 1837 he was created a Knight of the Legion of Honour; in 1840, a Conferenz-rath; in 1842, a Knight of the Prussian Order 'pour le Mérite dans les Sciences et les Arts'; in 1843, he received the Erlangen Diploma of Honour as Doctor of Medicine; and in 1847, the Grand Cross of the Dannebrog, which, as coming from his native land, he may be supposed to have prized the most.

Oersted was a man of simple and unassuming manners. His countenance, which glowed with the hues of health, had a singularly sweet and benevolent expression. He was greatly beloved by his students, being ever ready to assist them in a difficulty, not merely in their studies, but even in their pockets, if he found a deserving case of talent struggling with poverty. As a lecturer he was sometimes a little absent-minded, but in an endearing way; and the many thousands of every grade in Danish society who attended his classes during the long term of his professorship carried away with them a pleasing image of his gentle delivery, and the genuine delight which kindled in his eyes at the success of an experiment.

Apart from his university lectures he did a great deal to spread a knowledge of science amongst the people of Scandinavia, and was the first to institute popular lectures to ladies. Möller, one of his biographers, compares his agreeable and instructive mode of exposition with that of Alexander von Humboldt. Nor did his scientific work prevent his taking a lively interest in Danish literature and the political movements of the time. He contributed to the leading newspapers, and in 1829 assisted to found a monthly journal of literature, which continued until 1838. It succeeding in checking a species of criticism which threatened to destroy a healthy feeling for science and art. Oersted published many popular pieces in its columns, some of which reappeared in his important work, *The Soul in Nature*, published originally in German, and translated into English. This collection of scattered papers deals with various topics, such as poetry and religion, from the scientific point of view, and illustrates a conviction which brought an inward harmony into the life of its author, the conviction, in brief, that the universe is a manifestation of an Infinite Reason, and the laws of Nature are the 'thoughts of God.' From the conversation on the 'Spiritual in the Material,' we extract the following: 'Man is distinguished above all creatures on earth by this, namely, that reason, which all other animals unconsciously obey, in him is awakened to self-consciousness. He is thus a free agent; but, remember, only so far as is possible to a finite being.' From an address on 'The Cultivation of Science as an Exercise of Religion,' Oersted says: 'A love of knowledge, which some are frequently obliged to place secondary to other duties, with the man of science must be the occupation of his life; he is destined to nourish the holy flame of wisdom, which shall diffuse its rays amidst the rest of mankind; it is his nightly lamp which shall enlighten the earth. Woe to him if he does not consider his vocation to be a voice from heaven. Let this feeling of your high calling be deeply impressed upon you, my young friends, who to-day are to be received as members of our scientific union. It is only the conviction that while you devote yourselves to science you are, at the same time, honouring God, that will enable you constantly to preserve the courage and the power which your calling requires, and which you will fruitlessly seek in incentives from without. Each of you who have deliberately chosen the path of science must have felt that riches, whose glitter is so alluring to most people, must not be the highest aim of your endeavours, for it is too evident that this road leads least of all towards that idol of dazzled mortals. Many, among you will perhaps find a richer reward in honour, by which I do not mean that of the moment, but that which carries a name over the waves of time to distant races; and it is not to be denied that in a certain sense, we may say with one of the most glorious and most religious poets of the past century (Jean Paul) "that immortal fame is a grand thought, and is worthy of the toil of the noble-hearted." But if the immortality of a name were not borne up by a higher hope of immortality, if it were not an earthly type of an eternal life, what would it be but an empty vision, a shadow coming from no body, a rainbow without promise, which revealed no higher light through the drops of earthly matter? No, my friends, nothing but the conviction that our love of knowledge is an endeavour after a true reality, and that it is true life and true harmony, can give you a genuine, enthusiastic love of wisdom. The conviction that when you diffuse knowledge you are instrumental in the consolidation of God's kingdom on earth, can alone give you a true and unalloyed desire to lead those around you towards a higher light and higher knowledge. This, my young friends, is the important vocation for which you have begun to educate yourselves. Continue your endeavours with holy seriousness, and you will become capable of participating in a joy which the world cannot bestow, and your works will be a blessing to your fatherland ; yes, and will confer a benefit on the whole human race.' This quotation will serve to show that the mind of Oersted had not been contaminated by the baser motives of personal gain or notoriety. Nor was it materialised by constant working in the labyrinth of matter. Habits of precision had not dulled his vision to the poetry of Nature, or mechanical speculations robbed him of his inborn piety. He resembled in this the earlier philosophers, such as Thales and Pythagoras, who studied Nature from a pure love of wisdom.

The poetical vein which showed itself when Oersted was a boy again took form in a long lyrical and didactic poem, entitled the *Balloon*, which was translated into German in 1836. Some idea of its style may be gathered from the following extract:—

> 'Thales call,
> He whose enquiring mind paused musingly
> On the mysterious power, to action roused
> By amber rubbed. This power (to him) a spirit
> Woke from its slumbers by all-wondrous art.
> See how the spirit by our nurture grows !
> Let him behold it now as lightning gleam ;
> Teach him to look, led by the clearer light
> Of deep investigation, how the power,
> Which in the flashing lightning blinds the sight,
> Or in the rolling thunder deafening peals,
> Doth silent dwell in all material things,
> Be it in water, or in air, or earth,
> Or in the sifted ore ; as the spark lives
> In stone, by art from darkest night drawn thence,

And to the senses wonderful revealed
In all its varying forms; tasted in salt,
In heat and light perceived; now in the flame
It writhes, and in the faithful magnet now
Points a sure pathway to the mariner;
It lives in branch and leaf, in muscle strong,
And shrinking nerve; the eye material
Cannot detect it, yet is it revealed
To the soul luminous. Let him behold—
Then do thou well reflect how such a sight
Will move him. Call Pythagoras, and bid
The sage to mark the laws divine which rule
Each planet's course; and when he reads and sees
Such harmony amidst the countless worlds,
Trembling with joy his heart will overflow,
Before the sacred concert of high reason.'[1]

In politics Oersted attached himself to the party of progress. He co-operated in founding a society for securing the freedom of the press; and when Christian VIII., a lover of science, came to the throne he publicly hailed him as representing the more liberal ideas of the time.

On the 7th of November, 1850, the jubilee of Oersted's connection with the university was celebrated in Copenhagen with great rejoicing. Political differences were laid aside, and the people united in testifying their love and esteem for the veteran who had done so much for the glory and the welfare of their country. Deputations from the king and ministers, the professors and students, and other public institutions offered their congratulations. The king bestowed new titles on him, and the Government presented a country house near Copenhagen which had once been occupied by Oehlenschläger. At night the students marched by torchlight to his home, and united in singing verses to his praise. But though still looking hale and hearty the end was not far off, and in the beginning of next March an attack of cold set up an inflammation of the chest. He suffered little or no pain, but his strength rapidly declined, until on the 9th of the month he peacefully expired in the bosom of his family.

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[1] *The Soul in Nature.*

He was deeply regretted by the citizens of Copenhagen, and indeed by the whole of Denmark. On Sunday, March 16th, a [illegible] tudents laid a silver wreath upon his coffin, [illegible] singing some verses composed for the cerem [illegible] bore his remains, in the midst of torch-beare [illegible] e university, where they lay in state in a h [illegible] ed with black. On Tuesday, the 18th, they [illegible] moved to the Frue Kirke, famous for Thorwa [illegible] effigies of the twelve apostles. The bier was [illegible] by students of the Polytechnic School, and followed by a long procession of all classes. The Crown was represented by General von School and the Hereditary Prince of Denmark, the Government by the ministers and foreign ambassadors. A funeral march was played as they went along, the bells tolled, and the church was guarded by the civic infantry. Its interior was hung with mourning and illuminated with tapers. After the coffin had been placed on a catafalque in the midst, some verses were sung as a requiem and the eulogy pronounced by Dean Tryde. Thus, with royal honours, the beloved Oersted was carried to his grave, which is without the church.

Oersted once wrote a dialogue in which he advocated the erection of a statue to Tycho Brahe, the great Danish astronomer. It happened that his own was raised about the same time as Tycho's on an eminence in what is now the Oersted Park, Copenhagen, more than twenty-five years after his death, and unveiled in the presence of the king, queen, and ministers of state, together with a large concourse of people. Professor Holten, one of Oersted's earliest pupils, in referring to his old master on that occasion, said there was nothing in Oersted's outer man that might be [illegible] utiful, and yet his ap had a beauty of a high and noble order. His mobile features expressed every emotion of his mind, his bright eye beamed with benevolence, yet evinced a firmness of resolution which was founded on conviction. 'His look and voice told of the deep peace reigning in his heart, and which he guarded early and late. Honest and truthful, he had nothing to conceal, and required a devotion to truth as the first duty. But when he found untruth he grew angry, even extremely angry; yet not in a blaze of passion which overmastered him. His anger was a duty which he owed to the broken truth, and when he had spoken as he ought it vanished, leaving his face irradiated with peace and gentleness. He exacted much from himself, but was mild and charitable in judging of others, and always ready to assist or advise, encourage or console, as well as to forgive.'

He was an ardent patriot, and once wrote to the poet Goethe, 'I am by birth, memory, and language bound to Denmark. I am fixed to it by innumerable roots. It is not merely the soil, but the atmosphere in which I thrive the best. I cannot help working for it with all my might, and wish it all that an affectionate heart can desire. It is there, above all other spots on earth, that I should like my memory to be kept green and my race to flourish.'

Oersted's life offers an admirable example of the true man of science, working piously and purely at the discovery of truth in Nature; amiable in his domestic relations; seeking neither wealth nor distinction, and yet achieving both; spreading abroad the knowledge of material laws, without unsettling the spiritual faith; and preserving a wholesome interest in his country and his fellow men. Happily, Fortune bestowed upon him her highest favour, and seldom, if *ever, has the* golden luck of a great discovery fallen *to a more worthy* man.

ANDRÉ MARIE AMPÈRE.

ANDRÉ MARIE AMPÈRE.

THE electrical experiments of Ampère were directly inspired by the great discovery of Oersted, and may be regarded as a sequel to it by another hand.

André Marie Ampère was born at Lyons on January 22nd, 1775. He was the only son of Jean Jacques Ampère, a respectable merchant of the town, and Jeanne Antoinette Sarcey de Sutières, his wife, a woman of a good and pious character. Soon after the birth of André his father retired from business to a small property in the neighbouring village of Polémieux, on the Mont d'Or.

The child excited the wonder of his parents by an early turn for calculation. Before he knew his figures he loved to sit and calculate by setting out pebbles or kidney-beans upon the floor; and once, on his recovering from a severe illness, during which he was allowed no solid food, when his mother gave him a biscuit as a treat, he broke it up into little bits and began to reckon with them. On learning to read, his instinct drove him to the study of algebra. The modest library of his home did not contain all the books he wanted, so his father took him into Lyons, and presented him to the Abbé Dubarron, librarian of the college. Conceive the astonishment of the abbé when the little boy, who was barely twelve and small for his age, requested the works of Euler and Bernouilli! 'Bethink you,' explained the abbé, 'these books contain the differential calculus, and are among e most difficult that the human mind has produced.'

'Nevertheless, I hope to be able to understand them,' replied the child. 'But they are written in Latin,' said the abbé. This was an unexpected bar, for, though his father had begun to teach the boy Latin, he had left off, on seeing his taste for mathematics. However, with the help of M. Dubarron, this difficulty was soon overcome, and the lad was rendered happy with his toys of Euler and Bernouilli.

There was no school at Polémieux, and strictly speaking, Ampère had no teacher but his own genius. He followed his bent for the time being, and without any settled plan or method. At the age of eighteen he had worked through the *Mécanique Analytique* of Lagrange, and in later life he used to say that he knew as much of mathematics then as he ever did. But his reading embraced the whole round of knowledge. He read every book that came in his way, whether of history or travel, poetry or romance, philosophy or science. One of them was the great Encyclopedia of Diderot and D'Alembert, a compendium of learning in twenty folio volumes, the subjects following each other in alphabetic order. Ampère devoured it from beginning to end, article by article, without missing a line; and so retentive was his memory, that fifty years afterwards he could repeat long passages from the sections on Heraldry and Hawking. That upon Language aroused a strong desire to find the primitive speech which was confounded at the tower of Babel, and caused him to study several Oriental tongues, in particular the Sanscrit. He went so far as to compile the grammar and dictionary of a universal language.

Until the age of eighteen he was short-sighted without knowing it, and had taken the descriptions of fine scenery which he read for poetical exaggerations. *But, happening* to put on a pair of spectacles which fitted him, he realised for the first time how beautiful was the world, and fairly wept for joy. Ever afterwards he was, like Humphry Davy, an enthusiastic lover of Nature. His taste for music lay dormant still longer. It is related that on one occasion, at a musical soirée in Paris, Ampère could scarcely tolerate the strains of Gluck ; but a simple melody which followed reached his heart and moved him to tears. In examining his past life, when he was about eighteen, he remarked three prominent events which had greatly influenced him. These were his first communion, which deepened his religious feeling; the eulogy on Descartes pronounced by Thomas, which fostered his love of mathematics; and the taking of the Bastille, which strengthened his belief in the nobility of man. This faith was destined soon to receive an unexpected shock. Alarmed at the excesses of the Revolution, his father, a moderate man, had returned to Lyons, and become a *juge de paix* or magistrate. In the subsequent strife between the Jacobins or Anarchists, and the Girondins, or party of order, he was concerned in the trial of the violent Anarchist Chalier; who, on being sentenced, declared his death would cost the city dear. When Lyons was taken by the army of the Convention, and reprisals followed, Ampère the 'aristocrat,' as they chose to term him, was one of the first victims. He perished by the guillotine, after having pardoned his enemies, on the 24th of November, 1793. On the eve of his execution, he wrote a farewell letter to his wife, in Polémieux, which breathes alike the tenderness of a husband, the prudence of a father, and the resignation of a Christian martyr. In speaking of their modest fortune, he remarks that the books and instruments of geometry for André had een their chief expense; but regards it as a wise onomy, 'since he has never had any other master than himself;' and further on he adds: 'Do not tell Josephine of her father's misfortune; keep her innocent of it. As to my son, there is nothing that I do not expect of him. Whilst thou dost possess them, and they thee, embrace them in memory of me.'

Young Ampère, with his noble intelligence, had also an affectionate and tender heart; he had grieved much for the loss of an elder sister, who had cherished his infancy; and when he learned of his father's death, the blow was terrible. It seemed to blight his whole existence. For about a year he continued in a state bordering upon idiocy; he wandered aimlessly in the fields, and gazed at the sky, or sat by the roadside making piles of dust. If his comrades invited him to the woods, he was only, in his own words, 'a silent witness; a visitor without eyes or thought.' By-and-by, a copy of Rousseau's *Letters on Botany* fell into his hands, and roused his mind from its lethargy. At first he read the pages mechanically, but the charming style began to interest him, and he was tempted to go on. He became an eager botanist, ranging the hills and vales of the Mont d'Or with his herbarium in quest of specimens, which he planted in the garden at home, in their natural order. At this time, too, he chanced to open a volume at the ode of Horace to Licinius, in which the following lines occur:—

> 'The giant pine wind-shattered bends;
> On loftiest peaks the bolt descends.
>
> * * *
>
> Repine not for a short-lived sorrow,
> A happier sun shall shine to-morrow;
> Not always Phœbus bends his bow;
> Often his harp in accents low
> Awakes the silent Muse.'[1]

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[1] Sir Stephen de Vere.

The stanzas pleased, and drew him to the works of the Augustan poets. He became an excellent Latinist, and forty years later composed a hundred and fifty-eight correct verses, without help from a dictionary, while travelling in a post-chaise. Homer and Lucian, Tasso and Fénelon, Corneille and Voltaire, had been among his prior reading, but now his favourite was Horace, and he would recite long passages from the bard while roving in solitary spots on the out-look for plants. Catching the inspiration, he composed numerous pieces of his own; not merely songs and madrigals, but fragments of epics, tragedies, and what not. He meditated a great poem on the discovery of the new world by Columbus, to be called the *Américide*. His note-books of the time are fraught with these poetical vestiges, all freely interspersed with the x, y, z, of the algebraic formulæ, as the fossils of a tropical era are mingled with the Arctic shells of the glacial drift.

His mind had thus happily revived, and now his heart, prepared by poetry, was about to blossom. It was the spring of 1796, and Ampère had reached the age of twenty-one. He had been botanising at some distance from Polémieux, and in the evening, after sunset, was wending his way along the bank of a sequestered brook, when his eye lighted on two young ladies gathering posies in the meadow. The scene was idyllic; we can picture the streamlet fringed with poplars, the rich pasture teeming with cowslips and hyacinths, the glowing west and the poet-student struck with love. From that moment, before he knew who they were, he had resolved that one of the two maidens should be his wife. Her name was Julie Carron, and she belonged to a respectable family of his own station in the neighbouring village of St. Germain. The progress of his love is naively recorded in Ampère's diary under the title *Amorum.*[1] It begins with the entry: 'Sunday, April 10th.—I saw her for the first time;' and goes on to tell of his endeavours to see and speak with her; his acquaintance with her family, the books he borrowed from their library and returned a few days later, in the hope of meeting her. 'I was a few moments alone with her,' he writes. 'Sunday, September 4th.—I accompanied the two sisters after mass. I brought away the first volume of Bernardin. She told me that she should be alone, as her mother and sister were leaving on Wednesday. . . . Friday, September 9th.—I went there, and only found Élise [Julie's sister]. . . . Sunday, September 11th.—After mass I went to return Bernardin. I learned that she was coming back, but with Jenny.' Occasionally, he mixes up a little trigonometry with his passion, and teaches Julie how to find the height of the village steeple. At length the happy day arrived and the idyll came to a climax. On Monday, July 3rd, 1797, Julie came to Polémieux. 'At last,' he writes, 'they have come to see us at a quarter to four. We were in the alley, where I mounted the big cherry tree and threw down cherries to Julie, Élise, and my sister; everybody came. Afterwards, I gave my place to Francois (Julie's cousin), who lowered the branches, and we helped ourselves, which greatly amused Julie. They brought us luncheon. She seated herself upon a plank on the ground, with my sister and Élise, and I lay on the grass beside her. I ate some cherries which had been on her knees. We were all four in the large garden, where she accepted a lily from my hand. We went afterwards to see the brook. I gave her a hand to leap the little wall, and both hands to remount it. I sat beside her on the margin of the brook, far from Élise and my sister; we accompanied them in the evening to the windmill, where I sat again beside her to observe—we four. The setting sun gilded her dress with a charming light. She carried a second lily that I had given her in the large garden to take away.' In view of his marriage it was h time that Ampère earned his livelihood. Hitherto had lived at home and followed his bent for the no e. The parents of Julie wished him to become a mercer; but at a family council it was decided at he should give private lessons in mathematics at yons. He lodged there with a bookseller, M. Périsse, cousin of Julie, in the Rue Mercière, and joined a band of young men who met in the evenings and early mornings at the garret of one of them, Lenoir, in the Place des Cordeliers, to read Lavoisier's *Chemistry* and other books. Ampère kept up his acquaintance with these friends in later life.

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[1] Published with Ampère's Correspondence by Madame Cheveux, and *translated* into English.

He was married to Julie on the 15th Thermidor of the year 7, which being interpreted is the 2nd August, 1799. The religious ceremony was performed clandestinely, owing to the closure of the churches, and the civil one a few weeks later.

Ampère was now anxious to improve his position, especially as his wife bore him a son, Jean Jacques Antoine, on the 12th of August of the following year. n December 1801, he removed to Bourg, where he d obtained the chair of physics and chemistry in e Central School of the Department of Ain. Owing o the ill-health of his wife, he was compelled to leave her and his child at Lyons. Eager to do something which would gain him a more lucrative appointment, say, the professorship at some Lyceum, he published at Lyons, in 1802, a small treatise upon gaming, under he title of *Considérations sur la Théorie Mathé-*

matique du Jeu, in which he proved by algebra that a habitual gambler cannot escape ruin. A copy of the book was sent to Delambre, and presented by him to the Institute. It attracted some notice, and gave Ampère a certain reputation. On the recommendation of Delambre he was appointed in 1803 to the chair of mathematics and astronomy in the newly-founded Lyceum of Lyons. Ampère had realised his wish, and was now united to his family. But not for long. His wife grew worse, and in his diary, under the date 7th June, 1804, we find the prophetic entry: 'This day has decided the rest of my life.' A little later it is: '13th July, Wednesday.—*At nine in the morning!*' Julie was dead.

It was painful now to live in Lyons, and next year Ampère accepted an appointment as private tutor in analysis at the Polytechnic School of Paris, which had been offered to him through his patron Delambre. For years afterwards he regretted this step, characterising it as an act of signal folly. 'Oh! if I had only stayed in Lyons!' he would frequently exclaim, in a fit of nostalgia.

The philosophers of Paris were then divided into ideologists or metaphysicians, who sought to find out how the mind invents, and the scientists, who only sought to invent. Ampère became an ardent ideologist, and his doctrines exposed him to a good deal of ridicule from his professional brethren. He still devoted much of his time to mathematics, however, and increased his reputation by original memoirs. In 1806 he was appointed secretary to the Consulting Bureau des Arts et Métiers. In July of the same year he took to himself a second wife, by whom he had one daughter. In 1808 he was chosen Inspector-General to the University; and the following year was nominated to the chair of analytical calculus and mechanics in the Polytechnic School. In 1814 he was elected a member of the Institute.

Ampère has published a great variety of papers on mathematics, chemistry, physics, and natural history; but his name lives by virtue of his electrical researches. On Monday, September 11, 1820, the new discovery of Oersted was announced to the Institute by a member who had just returned from Geneva. Ampère was present, and seven days later he presented a paper to the Academy, giving a far more complete exposition of the discovery than Oersted himself had done, and proving by a series of new and beautiful experiments that all the magnetic effects could be produced by the electric current alone. It was entitled a 'Mémoire sur l'action mutuelle de deux courants électriques: sur celle qui existe entre un courant électrique et le globe terreste, et celle de deux aimants, l'un sur l'autre.' In this and subsequent papers during the next two years, he gave a definite rule for finding the direction in which a compass needle turns when a wire conveying a current is held near it, as in the experiment of Oersted, and fixed it in the memory by a simple device. He pictured a little manikin (or 'bonhomme d'Ampère' as it was called), to swim with the current while facing the needle; and showed that the north pole of the needle turned to its left, while the south pole turned to its right. By imagining oneself in the position of this manikin, the movement of the needle can be predicted, or, if the latter be observed, the direction of the disturbing current can be inferred. He also demonstrated the novel and important fact that two parallel wires, conveying electric currents, attract each other when the currents flow in the like directions, and repel each other when they flow in unlike or opposite directions.

e proved that the force of this attraction or repulsion was directly proportional to the strength of the currents, and inversely proportional to the square of the distance between them, a discovery which induced Clerk Maxwell to describe him as the 'Newton of electricity.' Ampère further showed that a spiral conductor or 'solenoid,' when traversed by a current, behaved exactly like a magnet, and possessed a north pole at one end, and a south pole at the other. It followed that such a helical conductor, if properly balanced, and free to swing, would set itself north and south, under the influence of the earth's magnetism; and Ampère constructed a delicate helix which imitated the movements of the compass needle. Finally, he promulgated the startling theory that every atom of magnetic matter in a magnet is so by virtue of a circular electric current enclosing it; and he suggested that the magnetism of the earth might be produced by currents circulating round its mass from west to east. In this way Ampère opened up a new domain of science, to which he applied the term electro-dynamics.

In a memoir read before the Academy of Sciences on October 2, 1820, Ampère, by parenthesis, describes a plan for an electric telegraph, which is based on the discovery of Oersted. He suggested having as many wires as there are letters of the alphabet, and placing a magnetic needle under each, so that when a current was sent through any of the wires from a distant station, the corresponding needle would move and signify a letter. The plan is feasible, and is one of the first on record in which the Voltaic electricity is applied to telegraphy. It was never carried out; but modified and improved plans were afterwards tried by others. In 1820 Schweigger of Halle found that the power of the wire over the needle was multiplied by winding it in a coil about the [illegible] V[illegible] [illegible] [illegible] Am[illegible]

[illegible] more approachable [illegible] Ampère. He was [illegible] a game of chess with a visitor; [illegible] argument; and [illegible] he were getting the worst [illegible] he provoked a discussion, [illegible] Davy's discovery that oxydised [illegible] declaring his belief that the [illegible] of magnetism was a chimera. Ampère [illegible] and lose the game. His discussions though carried on with a [illegible] never caused ill-feeling. On the contrary his good-humoured toleration and simple loyalty only endeared him the more. It took very little to excite Ampère and his son relates that in 18[illegible] when he was travelling by post-chaise to Hyères, for the cure of laryngitis, he proceeded to pay a relay

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[1] Davy also magnetised steel and iron filings by holding them [illegible] the current in a wire. See his letter to Wollaston, Nov. 12,

at Avignon, and became so impatient and upset over the little bill that no one could understand him. After the dispute was settled the postillion cried with an accent of disdain, 'There's a "dog" that's not clever! Where did *he* learn to count?'

The power of his intellect, and the vastness of his learning, made Ampère an eloquent, if rather long-winded talker. It is related that on one occasion when he was spending the evening with two friends, he held forth on the system of the world for thirteen hours at a stretch, and only finished then from sheer exhaustion. His credulity was proverbial. No fact in Nature was too strange, no event in politics too fantastic, for his acceptance. After the first surprise was over, his penetrating mind discerned a possibility where none else could; and for the rest, he never dreamed of doubting the word of his informant. He was sometimes cruelly hoaxed in consequence. Being afraid that some of his class were short-sighted like himself, and anxious that all should see his algebraic characters, he used to ask the pupils if he had made them large enough. Of course the students made him write them bigger and bigger until a very few figures monopolised the board. Like La Fontaine or Newton, he became a type of the absent-minded, and several amusing anecdotes are told of him. When heated with a demonstration on the black-board, he would sometimes rub out the figures with his silk handkerchief, and wipe his forehead with the duster. One day as he was walking along the street, absorbed in a mathematical problem, he saw an omnibus standing in front of him, and whipping out his chalk, began to write his formulæ upon the panel. He was on the point of achieving the desired solution when the whistle sounded, and the omnibus drew off. Another time, when he was crossing the Pont des Arts on his way to school, he picked up a mottled pebble and began to examine it. But suddenly remembering his class, he pulled out his watch, and finding he was late, hurried away, thrusting the stone into his fob and tossing his watch into the Seine.

In Ampère this eccentricity was a mark of genius. His absence of mind to the outer world came from his presence of mind to the inner. His consciousness had that power of focussing itself on its own problems, which distinguishes man above the brutes, and the thinker among ordinary men. His oddities of dress and manner, his rusty garb and awkward movements, were a frequent source of merriment to the foolish. The simple-minded Ampère was ignorant as a child of the pettiness and vulgarity of the world. He was better acquainted with the laws of Nature than the conventionalities of society. It is probable, as he himself thought, that if he had been sent to school and college in his youth, he would have known the world better; but his nature would also have lost some of its guileless innocence. Ampère was devoted to his home and family; he was a firm and sincere friend, and his feeling heart was open to all noble sentiments or aspirations. The execution of his father had not embittered his early enthusiasm for human liberty; and, in after years, the fall of Warsaw plunged him into despair.

From his childhood Ampère was a devout Christian, but the scepticism of the age infected him. 'Unhappy, that I am!' he exclaims; 'ancient ideas do not rule me sufficiently to make me happy; but they have still the power to strike me with terror. If I had kept them intact, I would not be cast into a gulf.' The poignancy of his internal conflicts may be gathered from the following passage in a letter to a friend at Lyons. 'Doubt,' he writes, 'is the greatest torment man can endure on earth.' His customary refuge in these crises was the Bible, the works of the Fathers, and the *Imitation of Christ.*

M. Arago, brother of the illustrious physicist, points to another source of unhappiness, in the miserable routine of pedagogy to which he was condemned. His household expenses, the cost of his apparatus, and the education of his son, who, after being introduced into the salon of Madame Récamier, became a distinguished man of letters, all helped to keep him in a state of genteel poverty during the best years of his life, and obliged him to eke out his salary by giving paid lessons. M. Arago thinks that Ampère's vocation was 'not to be a professor.' The work was neither suited to his health nor to his true aptitudes, and prevented him from developing the rich mine of his ideas. The contrast between what he did and what he might have done saddened him, and made him wish to inscribe upon his tomb,

HEREUX ENFIN ! (Happy at last !)

We know that Ampère's memoirs ranged over a wide field; and we are told, on good authority, that he only worked by fits and starts. It is probable, therefore, that the very universality of his mind, by tempting him into fresh paths, and the sensitiveness of his feelings, by distracting his heart and interrupting the current of his thoughts, prevented him, notwithstanding his great powers, from publishing more original books, and making other brilliant discoveries, such as are best achieved by dint of sustained effort in a particular direction. Towards the end of his life he became almost indifferent to his high position as a man of science. He published a treatise on the differential and integral calculus, but without either the author's name, title, or index.

In 1822, his papers on electricity, *Recueil d'Observations Electro-Dynamiques*, were published at Paris in one volume. His last was an *Essai sur la Philosophie des Sciences*, which he left unfinished, but which was published in 1838 and 1843. It develops a new classification of the sciences, which was, in spite of certain drawbacks, superior to all its predecessors. He began by dividing science into two great divisions, that dealing with the world of thought, and that concerned with the world of matter. Each of these two divisions was again subdivided into two others, in a natural manner, and each of these into two, until by this mode of fission a hundred and twenty-eight different sciences were obtained. Some of their names are verbal curiosities; for example, 'cœnolbology,' 'cybernetics,' 'technesthetics,' and 'terpnognosy.' The work, all incomplete, is a fitting monument to the prodigious learning of its author.

Ampère suffered from a chronic affection of the chest, and was already in feeble health when he left Paris, on May 17th, 1836, to make his tour as an inspector of the university. 6 He had improved his health, on former trips, by the gentle breezes of the Mediterranean, and hoped the air of Marseilles would now restore him. But he grew worse during the journey, and on reaching Marseilles was seized with acute brain-fever. He was nursed at the college; but spite of every attention, he passed away about five ock on the morning of June 10th, 1836. A few nents before he lost his consciousness, M. Desmps, the principal of the college, began to read a low voice some passages from the *Imitation*. mpère intimated that he knew the work by heart. These were his last words.

The news of his death was transmitted to Paris that day by the semaphore of Chappe, and caused a universal regret.

Ampère was an honorary member of the Royal Societies of London and Edinburgh, as well as the Academies of Berlin, Stockholm, Lisbon, and other cities. A statue in his honour was unveiled at Lyons on the 9th of October, 1888. It represents the philosopher seated in his chair, and in the act of meditation, with a quill in his right hand and a tablet in his left. The adoption of his name for the practical unit of electric current by the International Congress of Electricians is a more signal token of his universal renown.[1]

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[1] Till then 't was called the Weber, after the German physicist.

GEORG SIMON OHM.

GEORG SIMON OHM.

GEORG SIMON OHM was born at Erlangen, in Bavaria, on the 16th of March (or August), 1789.[1] He was the eldest son of a master locksmith, whose family had settled in the town at the end of the seventeenth century. The locksmith, though a poor man, was intelligent, and had some education. In his youth, a student of the Protestant university had lodged in his father's house, and given him lessons in arithmetic and geometry as part payment of the rent. He intended his two sons, Georg and Martin, to be locksmiths, like himself, but having learnt the value of knowledge, he determined to put them to the Gymnasium, after they had finished with the elementary school, that they might understand geometry, algebra, and physics. The cleverness of the boys attracted notice, and when, in 1804, Charles de Langstorff was appointed to the chair of mathematics, he predicted that they would be as famous some day as the brothers Bernouilli, and persuaded their father to release them from the bench and send them to the university. His prophecy has been realised, for Martin, the younger, became a distinguished mathematician, and died professor in the Military School of Berlin; while Georg immortalised his name as the discoverer of the law which governs the flow of the electric current.

With the help of a friendly bookseller at Erlangen, Georg was kept at the university for three terms.

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[1] Both dates are given.

The younger son then took his place, and he obtained a situation as private tutor in the Canton of Berne, and subsequently in Zurich, Switzerland. Returning to Erlangen in the year 1811, he passed his examination for *Privat-Docent* (private tutor) at the university, and was appointed to the Real Schule (School of Bamberg); but this institution was eventually closed, and Ohm was turned adrift before he could assist his father, who was growing feeble. It was the period of the wars with France, and Ohm, unable to obtain his proper employment, went back to Erlangen and worked at the vice. His *Essay on Geometry*, which, perhaps with some truth, was said to have been written in a room without a fire, may have helped to procure his appointment in 1817 as a teacher of mathematics in the Jesuit High School of Cologne. Ohm had the gift of teaching; but his higher aspirations led him to investigate the unknown law which regulated the flow of electricity in a conductor. Fourier had shown that the 'flux of heat' in a metal bar is directly proportional to the difference of temperature between its ends.[1] Ohm, by analogy, and partly from experiments made with apparatus constructed by himself, found that the electric current in a conductor is directly proportional to the difference of 'potentials' between its ends. He further showed that with the same difference of potentials, the current in different conductors is inversely proportional to the internal resistance of the conductor. It follows that the current obtained from a voltaic pile by connecting its poles through a wire so as to form a circuit, is directly proportional to the 'electromotive force' of the pile; that is to say, the difference of potentials between its poles, and inversely proportional to the internal resistance of the circuit, or, in other words, the joint resistance of the wire and of the pile. This golden rule of the electrician is now universally known as Ohm's law. It was heralded by contributions to the journal of Schweigger and Poggendorff's *Annalen* during the years 1825 and 1826, and fully published in a pamphlet entitled, *Die Galvanische Kette mathematische bearbeitet* (The Galvanic Chain Mathematically Worked Out), which appeared in 1827, at Berlin, where Ohm had gone on leave of absence to complete his experiments.[1] Incredible as it seems, his great discovery was still-born, and the pamphlet was soon ignored. Instead of fame and fortune, it brought its author misery and contempt. Critics derided his theory or doubted his results; and, to crown all, the Minister of Education, influenced no doubt by some antagonist, plainly intimated in his official capacity that a physicist who professed such heresies was unworthy to teach science. Wounded by this cruel rebuff, Ohm resigned his chair in the High School of Cologne, and retired into private life. Through this blind injustice, six of Ohm's best years were practically wasted at Erlangen; for though he solaced his isolation with research, he was too poor and disheartened to undertake important works. Papers of his on electrical subjects were printed in the journals of Kaestner and Schweigger, from 1829 to 1833, but they are of minor note. In the latter year the tide of his fortune began to flow again, and the Bavarian government appointed him to the chair of physics in the Polytechnic School of Nuremberg.

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[1] *Théorie Analytique de la Chaleur*.

At length Ohm's celebrated law, after a lapse of ten years, during which its services were lost to the world, began to find supporters; and towards the end of 1841 was publicly recognised by the Royal Society of

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[1] An English translation of *Die Galvanische Kette* was lished in 1841, and appears in Taylor's Scientific Memoirs.

London, who presented its discoverer with the Copley Medal. After all he had suffered at home, he was deeply touched by this mark of confidence and honour which came to him from abroad. It roused his genius and stimulated him to further effort. The man whom his countrymen had neglected now became their pride and ornament. The hour of his triumph had come at last, and it requited him for all their past misprision.

Among other physical researches he published a pamphlet, in 1843, on the theory of the siren, and the analysis of sounds by the ear. Being deficient in the musical sense, he had made the experiments with the help of a friend. For years he had planned a great work on molecular physics, to do for atoms what Sir Isaac Newton had done for the celestial orbs. The first volume appeared at Nuremberg in 1849, and was dedicated, out of gratitude, to the Royal Society. But the work was never finished, for towards the end of the year Ohm was called to Munich as Conservator of the Physical Museum (? Library of the Academy of Sciences), and other posts which trenched upon his leisure. He became a councillor of the telegraph administration, and in 1852 the professor of experimental physics in the university. Nevertheless, he composed a text-book on physics based on the lectures to his students, and published some articles on the luminous interference of crystals, partly anticipated by Professor Landberg of Christiania. If at a former time he had too little to do, he had now too much, and his multifarious duties began to undermine his health. In the early part of 1854 he was stricken with apoplexy. Although depressed by this visitation, he continued to lecture until the 6th (or 7th) of July,[1] but at ten o'clock that evening he died suddenly of another attack. Half-an-hour before he had been talking gaily with some friends about the ill-treatment he had received while at Cologne.

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[1] Both dates are given.

'So ended,' says Dr. Lamont, 'the noiseless career of a simple, modest, and highly-gifted man, who lived only for science.'[1] Ohm never sought, nor did he really find, that fortune and distinction which the world mistakes for happiness. His works did not attract the attention of the vulgar, and his professional status, and the Bavarian orders of merit of Maximilian and St. Michael which he received before his death, brought no advancement in his social rank. Indeed, Ohm did not wish it. He had a purer and deeper source of happiness in his own heart, the love of truth and the desire for knowledge. The outer world hardly knew of his existence; but his scholars loved him. Fond of solitude and contemplation, he had never married; he lived in a simple, self-dependent fashion, mostly alone, and perfectly content so long as he retained his health. Only during his illness did he ever ask the help of his near relatives.

We possess no portrait of Ohm except a bad photograph taken in 1846, from which the busts in the Academy of Sciences at Munich and in the Bavarian Pantheon have been executed. He was short of stature, and the expression of his countenance was at once earnest, kind and modest. He spoke but seldom, but always pithily, and frequently with wit and humour. In estimating the work of others he was just and generous, free alike from partiality or spite.

Dr. Lamont remarks that in science as in life his position was isolated and independent, and hints that if he had been more pushing and gregarious he might have occupied a higher niche in the temple of fame.

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[1] Dr. Lamont, Conservator of the Royal Observatory, Munich: *krede auf die Akademiker Dr. Thaddäus Siber und Dr. rg Simon Ohm.* Munich, 1855.

It is indeed probable that, had his first discovery been appreciated, his retirement from Cologne averted, and his official duties in later years of a lighter kind, he might have achieved far more. Still, it is hazardous to speculate on what might have been. Let us be thankful for what he did accomplish.

Since 1861 electricians have called the practical unit of electrical resistance by the name of 'Ohm,' and in 1884 the term was definitely adopted internationally by the Congress of Electricians which met in Paris. This commemoration of his services is to be supplemented by a public statue in the city of Munich, and a memorial tablet fixed upon the house where he was born.

MICHAEL FARADAY.

MICHAEL FARADAY.

MICHAEL FARADAY was born at Newington Butts, London, on the 22nd of September, 1791. He was the third child of James Faraday, a journeyman blacksmith, from the village of Clapham, in the West Riding of Yorkshire, and his wife, Margaret Hastwell, the daughter of a farmer near Kirkby Stephen, on the border of Westmoreland. James Faraday was a God-fearing man and a skilful artizan, who, in spite of his ill-health and the hard times, endeavoured to give his growing family some elementary education. He was well assisted by his faithful spouse, who, although illiterate, was a neat and frugal housekeeper. When Michael was about five years old they removed to a dwelling over a coach-house in Jacob's Well Mews, near Manchester Square, and the boy was sent to a common day-school to learn reading, writing, and arithmetic. Out of school he used to take his baby-sister for an airing, or play at marbles on the neighbouring pavement. Dr. Bence Jones informs us that during the distress of 1801, when the price of corn rose above £9 a quarter, the family obtained public relief, and Michael's portion was a loaf, which had to serve him for a week. At the age of thirteen he was taken on trial as an errand-boy by Mr. George Riebau, a bookseller, of No. 2, Blandford Street, close by, and one of his duties was to deliver the newspapers which were lent to customers. Faraday has told us that he was known as a 'great questioner,' d that on one occasion, while calling at a house, he thrust his head through the railings which separated it from the next, and began to ask himself whether he was on this side of the fence or the other, when the door opened, and caused him to draw back so suddenly that he made his nose bleed, and forgot all about his philosophic speculation. Years afterwards, when he was a great and famous man, he showed a kindness for his former calling. 'I always feel a tenderness for those boys,' he said to his niece, 'because I once carried newspapers myself.'

At the expiry of a year Mr. Riebau, 'in consideration of his faithful services,' took him as an apprentice to the bookbinding trade, without a premium, and encouraged his thirst for knowledge by allowing him to read books out of the shop. Watts' *Improvement of the Mind* was one of those which first taught him to think. Mrs. Marcet's *Conversations on Chemistry* and Miss Burney's *Evelina* were among his favourites, and an article on 'Electricity' in an *Encyclopædia Britannica*, which he was binding, turned his thoughts in that direction.

Reading did not content him, and it is a better sign of his natural genius that he devoted the few pence he could spare a week to making simple experiments in chemistry and the construction of electrical apparatus. His first electrical machine was made with a glass phial, but afterwards he procured a real cylinder. To amuse and instruct himself, he also began to keep a scrap-book, which he styled 'The Philosophical Miscellany,' and among the extracts from different periodicals which it contains is a notice of Mr. Davy's great discovery, the decomposition of the fixed alkalis.

'Do not suppose that I was a very deep thinker, or was marked as a precocious person,' said Faraday, in speaking of this era. 'I was a very lively, imaginative person, and could believe the *Arabian Nights* as easily as the *Encyclopædia*, but facts were important to me, and saved me. I could trust a fact, and always cross-examined an assertion.'

Another of his patrons was M. Masquerier, a French artist, who, after witnessing the Revolution, and painting a portrait of the great Napoleon, was then a refugee in London, where he lodged with Mr. Riebau. Faraday had shown a taste for drawing, especially vignettes, and M. Masquerier lent him Taylor's *Perspective*.

In his nineteenth year Faraday saw from a bill in a shop window that Mr. Tatum delivered evening lectures on natural philosophy at 53, Dorset Street. The admission to each was a shilling; but his elder brother Robert, a working blacksmith, helped him to the necessary sum. At Mr. Tatum's he made the acquaintance of some earnest young students, and among them Mr. Benjamin Abbott, a Quaker, who preserved his letters, which show that Faraday even then was as much a scholar and a gentleman as if he had been born in the purple.[1]

Faraday wrote out his notes of Mr. Tatum's lectures, and illustrated them with careful drawings of the experiments, then bound them himself, and dedicated the four volumes to his kind master, George Riebau.

In the spring of 1812, Mr. Dance, a customer of Mr. Riebau, and a member of the Royal Institution, took Faraday to four of the last lectures delivered there by Sir Humphry Davy. This was a grand treat for the young man, who sat in the gallery over the clock, and made copious notes, which he afterwards wrote out, and bound in a neat quarto volume. His desire to be engaged in scientific work, even of the 2/

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[1] See Dr. H. Bence Jones' *Life and Letters of Faraday*.

lowest kind, induced him, he says, to write, in his ignorance of the world and the simplicity of his heart, to Sir Joseph Banks, then President of the Royal Society. Naturally enough, 'No answer' was the message brought back by the porter; but there is something pathetic in this endeavour of a poor and humble youth to reach his true vocation.

On the 7th of October, 1812, his apprenticeship ended, and the next day he began work as a journeyman under an ill-tempered master, whom he thought of leaving, in spite of an inducement to remain. Towards the end of the year, in his anxiety to escape from trade, which he considered vicious and selfish, and his love for science, which, he imagined, made its pursuers amiable and liberal, he took the 'bold and simple step' of writing to Sir Humphry Davy, expressing the hope that if an opportunity came in his way, he would favour him, and at the same time sent the quarto volume of lecture notes. Davy, it seems, consulted his friend Mr. Pepys, of the Poultry. 'Pepys,' said he, 'what am I to do? Here is a letter from a young man named Faraday: he has been attending my lectures, and wants me to give him employment at the Royal Institution. *What can I do?*' '*Do?*' echoed Pepys; 'put him to wash bottles: if he is good for anything, he will do it directly; if he refuses, he is good for nothing.' 'No, no,' replied Davy; 'we must try him with something better than that.'

He sent for Faraday, and spoke to him in the ante-room of the theatre, advising him to stick to his business, and assuring him that Science was a harsh mistress from a pecuniary point of view. He smiled at the young man's notion about the superior moral feeling of philosophers, and said he would leave it to the experience of a few years to set him right on that score. But he promised him the bookbinding of the Institution and of himself and friends.

It was, doubtless, with a mingled feeling of gratitude and disappointment that Faraday returned to his humble home in Weymouth Street, where he was living with his widowed mother. But a few months later, while he was undressing one night, he was startled by a loud knock, and on looking out, observed Sir Humphry's carriage standing at the door. The powdered footman delivered a note from Sir Humphry, requesting his attendance at the Institution in the morning. It appeared that the laboratory assistant had been discharged for misconduct, and Sir Humphry offered the place to Faraday, who accepted it.

In thus playing the good fairy to the deserving bookbinder, Davy not only made the greatest of his discoveries, but performed one of the kindest and most memorable acts of his life.[1]

Faraday's engagement at the Royal Institution began on March 1, 1813. His duties were to assist the lecturers, and keep the apparatus clean. For this he received a weekly wage of twenty-five shillings, and a lodging at the top of the house. The post was humble, and the work a trifle menial, but it was the kind his heart was craving. At length his foot was planted on the lowest rung of the ladder he desired to mount. He was more than satisfied, and, indeed, it was as much as he could then expect. But from the first he improved on his position. In a few days he began to extract sugar from beetroot, and he put the collection of minerals in order. Davy was then studying the properties of the new compound, chloride of nitrogen, and had more than once injured himself by its explosion. On one of these occasions, Faraday, before his engagement at the Institution, had served as his amanuensis for a few days, but now in assisting Davy his own life was in some danger. While holding a small tube containing a few grains of the capricious substance in his hand, he brought a piece of warm cement near it, and was instantly stunned. On coming to, he found himself standing with his hand in the same posture, but his fingers were lacerated with the shattered tube, and the mask shielding his face was fractured by the concussion.

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[1] Bergman, the Swedish chemist, said his greatest discovery was Scheele, and the saying has been applied to Davy in this connection.

In the evenings Faraday continued his self-culture, or beguiled the hours with song and flute. He was admitted as a member of the City Philosophical Society, a band of young men who met once a week for mutual improvement; and some of the members came to his own rooms, to read together and correct each other's style and pronunciation. Faraday was doing his best to supply the lack of a college education, and it is wonderful how well he succeeded. Even the finish of a tour abroad was not denied him, for he accompanied Sir Humphry Davy as amanuensis and experimental assistant, during his visit to the Continent in the autumn of 1813. Besides enlarging his mind, and stocking his imagination with memorable pictures, this excursion introduced him to the notice of the most famous living philosophers, several of whom became his friends.

On his return to London he was re-engaged at the Royal Institution on somewhat better terms. Encouraged by Davy, he began to perform simple analyses. The first recorded in the note-book of the laboratory in Faraday's writing is on 'Dutch turf ash.' On January 17, 1816, he delivered his first lecture to the City Philosophical Society, on the general properties of matter, and in the same year his first paper was published in the *Quarterly Journal of Science*, connected with the Institution. It describes an analysis of caustic lime from Tuscany.

As yet he had not made an original discovery. He was merely training himself, and assisting in a quiet and modest way, at the lectures of Mr. Brande. Thanks to his effective help, Mr. Brande's occupation is described as 'lecturing on velvet.'[1]

In 1820, however, a paper of his on two novel compounds formed by the union of carbon with chlorine and iodine, was read before the Royal Society on December 21, and published in the *Philosophical Transactions*. At this time the experiments of Ampère were the talk of scientific men, and Mr. Wollaston attempted to make the magnetic needle rotate round the wire carrying the current, and *vice versâ.* He tried an experiment of the kind in the laboratory of the Institution, but failed of the result. Faraday was present, and turned his attention to the matter. He first informed himself of what had been done by others, and published a *History of the Progress of Electro-Magnetism* in Thomson's *Annals of Philosophy*. To write a paper was, he considered, a good way of getting a clear insight into a subject. Then he began to try the experiment of Wollaston, and finally succeeded. When the needle and wire began to revolve around each other he danced about them with delight, exclaiming, 'There they go, there they go!' To give himself a treat, he went to Astley's Circus to see the horses. At the pit entrance there was a crush, in which a big fellow pushed the laboratory lad who was with him. Faraday, who could never tolerate injustice, bristled up in his defence.[2]

Like his father before him, Faraday belonged to the religious sect known as the Glassites or Sandemanians, a brotherhood of Christians who eschewed the ceremonial of the established churches, and, taking the Scriptures for their sole authority, endeavoured to mould their lives after the example set by the Apostles. One of the Elders of that body in London was Mr. John Barnard, a silversmith, of Paternoster Row, and Faraday was a visitor at his house. He became attached to Sarah, the third daughter of Mr. Barnard, and proposed for her hand. 'You know me as well or better than I do myself,' he wrote. 'You know my former prejudices and present thoughts—you know my weaknesses, my vanity, my whole mind ; you have converted me from one erroneous way, let me hope you will attempt to correct what others are wrong. . . . Again, and again, I attempt to say what I feel, but I cannot. Let me, however, claim not to be the selfish being that wishes to bind your affections for his own sake only. In whatever way I can best minister to your happiness, either by assiduity or by absence, it shall be done. Do not injure me by withdrawing your friendship, or punish me for aiming to be more than a friend by making me less ; and if you cannot grant me more, leave me what I possess, but hear me.'

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[1] *Faraday as a Discoverer*, by John Tyndall.

[2] Dr. Gladstone's *Life of Faraday*.

Miss Barnard hesitated, and Faraday followed her to Margate. From thence they went to Dover and Shakespeare's Cliff, and Faraday returned to London full of hope and happiness. He loved her with a warm and chivalrous affection, which only became deeper as time went on.

On his marriage he took his bride home to the Royal Institution, where he had been appointed the superintendent of the laboratory. More than twenty years afterwards he wrote in his book of diplomas : 'January 25, 1847.—Amongst these records and events, I here insert the date of one which, as a source of honour and happiness, far exceeds all the rest. We were *married* on June 12, 1821. M. Faraday.'

The young 'philosopher'—a word he preferred to 'physicist'—was now employing his spare time in original work. He attempted to harden steel and preserve it from rusting by admixture of platinum and the nobler metals; but with no practical result beyond a few doubtful razors, which he presented to his friends.

Another venture was more successful. On the 5th of March, 1823, following a suggestion of Davy, he warmed the hydrate of chlorine in a sealed tube until it became filled with yellow fumes. While thus engaged Dr. Paris, the biographer of Davy, called at the laboratory, and, seeing some oil on the glass, rallied him for using dirty vessels. Faraday was surprised at the liquid, and proceeded to file off the end of the tube, when it suddenly exploded and the oil vanished. Next morning Dr. Paris received the following characteristic note,—

'DEAR SIR,—The *oil* you noticed yesterday turns out to be liquid chlorine.

'Yours faithfully,
'M. FARADAY.'[1]

The yellow gas, confined in the heated tube, had been liquefied by its own pressure. The new product was subsequently applied as a disinfectant in Millbank Penitentiary, where a fever had broken out. But this, and other liquefactions of the kind, was chiefly valuable in pointing out that a gas is merely the vapour of some liquid. In one of these experiments no less than thirteen pieces of glass were driven into one of his eyes by an explosion.

Among his chemical discoveries at this time the most important was the new hydro-carbon, benzol, which forms the basis of our splendid aniline dyes. Its separation is described in the *Philosophical Transactions* for 1825.

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[1] Dr. Paris, *Life of Sir H. Davy*.

By the influence of Davy, his protector, Faraday was made Director of the laboratory, while Mr. Brande was appointed Professor of Chemistry. One of his first acts on his promotion was to institute weekly gatherings of members interested in science. They met in the laboratory to discuss new inventions or discoveries, and the practice finally developed into the Friday Evening Discourses which attract so many to the Royal Institution.

In the spring of 1827 Faraday delivered a series of lectures on chemical manipulation at the London Institution, and also his first course at the Royal Institution on chemical philosophy. At Christmas he began those delightful lectures to juveniles home for the holidays which are still in vogue.

As a member of a committee of the Royal Society, he was now engaged in preparing a good glass for optical purposes. Borate of lead when fused makes a limpid glass, with a high refractive index, but soft in quality, and Faraday tried to harden it by adding silica. Mr. Benjamin Abbott informs us that Mr. Anderson, an old sergeant of the Royal Artillery, who assisted in the laboratory, and never did less nor more than he was told, attended to the furnaces. His duty was to keep them at the same heat, and the water in the ash-pit at the same level. In the evening he was relieved, but one night Faraday forgot to tell him that he might go home, and in the morning found the faithful stoker at his post. The new glass was to all intents and purposes a failure; but it was afterwards utilised by Faraday in his great and signal discovery of the 'magnetisation of light.'

The professorship of chemistry at the London University was offered to Faraday, but he declined it. In 1829, however, and for the next twenty years, he delivered lectures at the Royal Military Academy of Woolwich. His salary at the Royal Institution was only £100 per annum, with house, coals, and candles; but he eked it out by commercial analyses and scientific evidence. In 1830 his income from this external source was about £1000, and the following year it was considerably more. We cannot doubt that with avarice for a motive, and lucre for an aim, his fortune from commercial work and the royalties on his patents, must have become enormous. He was now at the 'parting of the ways'—one luring him to opulence and power, the other to immortal fame and science. It was meet to choose between them, for a man cannot serve both God and Mammon. But there was little or no vulgar ambition lurking in the soul of Faraday. He had already proved his genius for research, and felt the rare joys of discovery. Heart and head were both enlisted in the service of philosophy. What wonder if his choice were easily made?

In 1831 he made the greatest of his discoveries, the production of electricity from magnetism; and henceforth his professional fees declined. He devoted himself almost entirely to the labours of the investigator.

A body with a stagnant or static charge of electricity attracts or repels another body with a static charge; and, similarly, Ampère had shown that a conductor carrying a current or dynamic charge of electricity attracts or repels another conductor with a dynamic charge. Further, a body with a static charge *induces* a charge of an opposite kind on the neighbouring bodies. It was left for Faraday to prove that a conductor carrying a current also induces currents in the neighbouring conductors.

He wound two helices of insulated wire on a wooden core, and sent the current from a battery through one, while the other was connected to a galvanometer, or sensitive current-measurer, based on the discovery of Oersted. As long as the battery current flowed steadily through the helix, the needle of the galvanometer was still; but on *starting* or *stopping* the battery-current he noticed the needle flinch. In this way he discovered that when a current starts in a conductor it induces a current in a neighbouring conductor, which lasts but for a moment, and flows in the opposite direction to the exciting current. Again, when a current stops in a conductor, it induces a momentary current in a neighbouring conductor, which flows in the same direction as the exciting current. While the current steadily flows it does not seem to alter the neighbouring conductors; but if it suddenly increase or diminish in strength, a corresponding induction takes place. Moreover, if the active current is made to approach or recede from the passive conductor, it induces an unlike or like current in the latter during its motion. In short, it is only during a *change* in the relations of the two conductors that the induction becomes manifest.

Ampère had shown that a helix of wire conveying a current is virtually a magnet; and M. Arago, the astronomer, had magnetised iron by placing it within the hollow of such a helix. Faraday thought the action might be reciprocal, and that as electricity produced magnetism, so magnetism might produce electricity. He took a welded ring of iron and wound a coil of insulated wire on each half of it. One coil was connected to a galvanometer, the other to a battery, in order to magnetise the iron. When the current was started in the magnetising coil, the needle of the galvanometer whirled round several times and came to rest. No effect was observable while the current steadily flowed. But when the current was stopped the needle whirled again in the reverse direction. To prove that this momentary current was caused by the magnetism [illegible] by mere induction, as in his prior experim[illegible]bstituted a ring of copper, a 'non-magnetic' me[illegible] the iron, and found it much reduced. Moreo[illegible] obtained a similar effect, without employin[illegible]current, by simply thrusting a steel magnet in[illegible]e ring. When the magnet was shifted to or f[illegible]he ring, a pulse of current was set up in the coil, [illegible]l the needle of the galvanometer swung round to one side or the other. Here, again, the induction only showed itself whilst a change was taking place.

It was on the 29th of August, 1831, that Faraday detected the first signs of a current thus produced by magnetism. On the 8th of February, 1832, he made the following entry in his note-book: 'This evening, at Woolwich, experimented with magnet, and for the first time got the magnetic spark itself. Connected ends of a helix into two general ends, and then crossed the wires in such a way that a blow at *a b* would open them a little. Then bringing *a b* against the poles of a magnet, the ends were disjoined, and bright sparks resulted.' With points of charcoal on the wires, the tiny spark was visible as a small electric arc.

This experiment was aptly described by Mr. Herbert Mayo in the following impromptu :—

'Around the magnet Faraday
Is sure that Volta's lightnings play:
    But how to draw them from the wire?
He took a lesson from the heart:
'Tis when we meet, 'tis when we part,
    Breaks forth the electric fire.'

e little iron ring, and its calico-covered coils, with which Faraday made this great discovery of magneto-electricity, as he termed it, has been preserved in the museum of the Royal Institution, along with some of the books he bound, and the electrical machine he made while still an apprentice.

Magneto-electric induction enabled Faraday to explain the curious phenomenon which had been observed by Arago in 1824. When a copper disc is rotated above a compass, the needle tries to follow it round. Further, an oscillating compass needle is quickly brought to rest by a copper plate above or below it. Faraday spun a copper disc between the poles of a magnet, and found that a current of electricity was generated in it. Subsequent researches proved that whenever a conductor crosses the 'lines of magnetic force,' as he called them, in the neighbourhood of a magnet, a current is generated in it, and the strength of the current is proportional to the number of lines cut by the conductor in a second. Thus, for the production of magneto-electricity, it is necessary that the lines of force should traverse the conductor; but this may be done either by moving the magnet while the conductor is at rest, or by moving the conductor while the magnet is at rest, or by moving both conductor and magnet. Again, the mere excitation of magnetism in the neighbourhood of a conductor, so as to send the lines of force across it, will excite a current in it.

The twin discoveries of electro-dynamic induction and magneto-electric induction were communicated to the Royal Society on November 24th, 1831.

Faraday refrained from applying them to practical purposes. 'I have rather been desirous,' he says, 'of discovering new facts and new relations dependent on magneto-electric induction than of exalting the force of those already obtained, being assured that the latter would find their full development hereafter.'

His assurance has been amply justified by the construction of the induction coil, the application of 'Faradic' currents in medicine, the improvement of the dynamo-electric generator, and the invention of the magneto-electric telephone. The 'dynamo' is now universally employed in the production of currents for electro-plating, telegraphing, electric lighting, and the transmission of power.

It followed from his researches that if a coil of wire were rotated across the lines of terrestrial magnetism, a current would be induced in it; and this was found to be the case. His experiments on the matter formed the subject of the Bakerian lecture for 1832.

In 1833 he was appointed to the new professorship of chemistry which had been founded by Mr. John Fuller, M.P., at the Royal Institution.

One day in 1834, a young man named William Jenkins, at the conclusion of a lecture, mentioned to him that, in breaking the circuit of an electro-magnet, he had received a smart shock from the ends of the wires held in his hands. Faraday used to say this was the only fruitful suggestion, out of many, that was ever made to him. He investigated the matter, and discovered what is known as 'self-induction,' or in other words, that a current on starting and stopping in a conductor induces a momentary current in that conductor, just as it induces one in a neighbouring conductor. As the induced current on starting is contrary to the exciting current, it has the effect of weakening the latter; and as on stopping it is in the same direction as the exciting current, it enhances the latter, producing what Faraday called the 'extra current.' It was this extra current which produced the shock upon its first observer. The discovery was published to the Royal Society on January 29th, 1835.

Faraday next undertook a series of investigations on the phenomena of the voltaic pile and the laws of electro-chemical decomposition, in the course of which he introduced some new terms, which are now familiar. Thus, 'electrode,' with its derivatives 'anode' and 'cathode,' are used instead of the positive and negative poles of a battery wire, while 'ion' stands for the product of electrolysis, 'anion' and 'cation' being those respectively liberated at the anode and cathode.

In 1835, Lord Melbourne offered Faraday a pension of £300 a year, but in a manner which seemed to reflect on the honour of 'philosophers,' and Faraday declined it. However, the offer was repeated, and Faraday was induced to accept it. The following year he became a scientific adviser to the Trinity House on marine lights, buoys, and beacons, but rather from a patriotic motive than a desire to increase his income or engage in outside work, for his set purpose was original discovery.

Since Newton had revealed the law of gravitation, it was usual to speak of 'action at a distance,' though Newton himself regarded the view as 'so great an absurdity,' that no man 'who has in philosophical matters a competent faculty of thinking can ever fall into it.' 'Gravitation,' he wrote in a letter to Bentley, 'must be caused by an agent acting constantly, according to certain laws.' In like manner, since Coulomb had disclosed the laws of electric and magnetic forces, the hypothesis of action at a distance was applied to them. But Faraday's researches on induction had led him to surmise the existence of some invisible agent between the inducing body and the induced. Iron filings when sprinkled round the poles of a magnet, or a wire conveying a current, arrange themselves in curves, which, in his opinion, were the lines of 'force' or strain in the magnetic field. This idea was strengthened by the discovery that induction between one charged conductor and another was influenced by the intervening medium or 'dielectric,' as it was called. Thus, when plates of shellac, or sulphur, or spermaceti were interposed between the two conductors, the induction of one on the other was different. Moreover, the electricity was found to penetrate the dielectric, as though it were absorbed for a time and then restored. Faraday called this property of dielectrics its *specific inductive capacity*, and he endeavoured to explain it by picturing the molecules of the dielectric between the two conductors as being 'polarized' by the electric charge. These experiments were described to the Royal Society on December 31st, 1837. It is from this discovery that the name of 'Farad' has been given to the unit of electrical capacity.

The following March, his mother died at Islington. She had been widowed since October 1810, and Faraday had supported her declining years. She used to visit him at the Royal Institution, and although she did not understand the mysteries of his work, she was always very proud of him.

Weary from overwork, in the summer of 1841, Faraday took a holiday in Switzerland with his wife, and her brother Mr. George Barnard, the artist. He was a great admirer of fine scenery, and loved to witness a splendid sunset or a terrific thunderstorm. He has been known to hail a cab and drive through the pelting rain in the direction of the lightning. But whether his thoughts on these displays were those of the poet or the man of science, it is difficult to say. At Eastbourne, once a gentleman found him in the midst of a thunderstorm rubbing his hands with delight because he had seen a flash of lightning strike the tower of a church. His journals show that he enjoyed the scenery of Switzerland. Of the Geissbach fall, at Brienz Lake, he wrote, 'The sun shone brightly, and the rainbows seen from various points were very beautiful. One at the bottom of a fine but furious fall was very pleasant. There it remained motionless, whilst the gusts and clouds of spray swept furiously across its place and were dashed against the rock. It looked like a spirit strong in faith and steadfast in the midst of the storm of passions sweeping across it, and though it might fade and revive, still it held on to the rock as in hope and giving hope, and the very drops which in the whirlwind of their fury seemed as if they would carry all away, were made to revive it and give it greater beauty.

'How often are the things we fear and esteem as troubles made to become blessings to those who are led to receive them with humility and patience!'

Faraday's mind was still brooding on the problem of induction, and trying to reveal the inner process of the magnetic field. 'How wonderful and mysterious is that power you have there!' he exclaimed one day to his assistant, who was working with a magnet. 'The more I think over it, the less I seem to know.'

Some inkling of its true nature was got by a magnificent experiment.

In a ray of plane polarized light the vibrations of the luminiferous ether are restricted to one plane, and hence in passing through a translucent body it is more sensitive to a change in the physical structure of the body than an ordinary ray, in which the vibrations are in all directions. Faraday knew that such a ray was a delicate index of the molecular state, and he employed it as a detective. Placing a piece of his heavy glass between the poles of a horse-shoe magnet, he sent a ray of polarized light through it from one pole to the other. The ray was polarized by a Nicol prism, which confined its vibrations to a vertical direction. After traversing the glass it was intercepted by a second Nicol prism, which only permitted the horizontal vibrations of a ray to pass. To an eye looking into this prism all was dark; but on exciting the magnet with an electric current, the plane of polarization was twisted round until the vertical vibrations penetrated the second prism, and the eye could see the light. The ray travelled along the 'lines of force' of the magnet, and the plane was rotated in the same direction as a right-hand screw advancing with the ray. This result was a revelation. It showed that magnetism was capable of affecting the luminiferous ether which is the vehicle of light, either directly or indirectly through the glass, and it was the first proof of a connection between light and electricity.

If we cannot thus far term it the greatest of Faraday's discoveries, it is certainly the most original; and since it opens up a new domain, at present unexplored, we may not realize its full importance. Like an outpost which has been planted by some daring traveller in some unknown land, it stands in waiting for the future. Professor Tyndall has compared it to the 'Weisshorn among mountains—high, beautiful, alone.' It was announced to the Royal Society on November 20th, 1845, in a memoir entitled, 'On the Magnetisation of Light, and the Illumination of Magnetic Lines of Force.'

At this period, Faraday was engaged in many other researches on magnetism. He announced the discovery of diamagnetism in a paper to the Royal Society on the 'Magnetic Condition of all Matter,' which was read on December 18th, 1845. Magne-crystallic action, or the behaviour of crystals in the magnetic field, was another branch of investigation. Faraday, indeed, was fascinated by the study of magnetism. When he was asked which he considered the most wonderful, magnetism or electricity, he is said to have responded, 'Magnetism,' for it was universal, whereas electricity was temporary and local.

He also conducted experiments on frictional electricity, and the *gymnotus*, or electric eel, so that no department of the science was neglected by him. In the *Philosophical Magazine* for March 1848, he described the electrical properties of gutta-percha, which was afterwards used for insulating submarine cables and other conductors. The specific inductive capacity of gutta-percha was such as threatened to retard the speed of a signal on the proposed Atlantic cable. Mr. Cyrus Field consulted Faraday, who made some experiments, and reported: 'It can be done, but you will not get an instantaneous message.' 'How long will it take?' inquired Mr. Field. 'Oh, perhaps a second.' 'Well, that's quick enough for me,' concluded the American. The enterprise succeeded in the end, and by improved methods the period of a signal has been shortened.

The catalogue of the Royal Society gives a list of 158 scientific memoirs contributed by Faraday. Some of them are brief notices, but the majority represent a prodigious number of experiments. For he was a ruthless cross-examiner of Nature, and multiplied his questions until there was no room for doubt. A selection was published by their author in three volumes, headed *Experimental Researches in Electricity*, and including his principal discoveries in this department from the year 1831 to 1855. This classic work is one of the richest treasuries of knowledge at first hand which has ever been presented to the world by a single intellect.

Faraday also published a treatise on *Chemical Manipulation*, and some of his lectures were printed, notably a course to juveniles on the chemical history of a candle, which is a good example of his clear and definite style—the style, in short, of an accurate and lucid thinker.

Faraday was neat, orderly, and punctual in his habits. After eight hours of sleep, he rose in time for breakfast at eight o'clock, and, after a survey of the Institution, descended to the laboratory. He did not make an experiment at random, trusting to chance for a result. Nor was he a mere measurer of known effects. His method was a golden mean betwixt these opposite extremes. He formed an idea, and planned the experiments required to test it. A list of the apparatus he should want was given to his assistant; and if a new piece was needed he gave the maker full instructions. A glance at the table showed him that all had been prepared, and nothing more. Then he would don an apron which had seen good service, rub his hands together, and begin. At first his face is grave, and there is perfect silence in the laboratory. But if the result answers to his expectation his eyes gleam with satisfaction, he hums a tune, swings from side to side on either foot, or talks in a rapid, eager manner to his assistant. Sometimes a doubt casts a shadow over his expressive features for a moment. A new experiment has to be arranged to try another suggestion. His movements are quick, yet calm and sure, like the process of his mind.

When the experiment is finished, each tool is put back in its appointed place. For he will not tolerate any carelessness. There must not be a bottle without its topper, or rubbish lying on the floor, or an evil smell, or a grating machine. He dines at half-past two, then retires to his study, with its plain furniture and india-rubber plant in the window, to meditate on his results, or shape the notes he has taken into a paper for the Royal Society. He is exact and careful in this too, arranging them in sections and numbered paragraphs easy of reference. First, he states the subject, then the negative results obtained, and finally the positive. This writing is the hardest part of all. For he is a severe critic, and too cautious, too fond of indubitable fact, to publish more than has been strictly proven. Even after a memoir had appeared he wished to improve it. On the fly-leaf of a collection, bound in 1832, he wrote: 'As I never looked over one of my papers a year after it was written, without believing, both in philosophy and manner, it could have been much better done, I still hope the collection may be of great use to me.'

He was economical of means on principle. In *Chemical Manipulation* he wrote: 'The person who could devise only, without knowing how to perform, would not be able to extend his knowledge far, or make it useful; and where every doubt or question that arises in the mind is best answered by the result of an experiment, whatever enables the philosopher to perform the experiment in the simplest, quickest, and most direct manner, cannot but be esteemed by him as of the utmost value.' Many of his tests and devices were as happy as they were simple. For instance, when he was afloat on the Channel, observing the light on Dungeness, his pocket photometer was a shawl-pin with a black head, which reflected an image of the beam. Sailing one day in a penny steamer, he was struck with the foul condition of the Thames, and tearing up some white cards, he wetted and dropped them into the river. Sinking quickly out of sight, they showed the dirtiness of the water. 'He who understands how to put appropriate questions to Nature generally knows how to extract the answers by simple means,' says Schönbein; 'and he who lacks this capacity will not, I fear, obtain a profitable result, though every conceivable tool and apparatus may be ready to his hand.' Forethought, skill, and tidiness enabled Faraday to save both his time and materials. His accounts of expenditure were also kept with scrupulous care.

Like Sir Humphry Davy, he was a fascinating lecturer. The subject was well considered, and an outline of the discourse written on a sheet of foolscap, with the experiments numbered. The apparatus was pre-arranged on the table, in order that each experiment could be seen by the whole audience, and nothing should obstruct the lecturer.

It is a Friday evening discourse. The lighted theatre is filled to overflowing with a fashionable and distinguished audience in evening dress. But for the uncouth apparatus on the horse-shoe table, one might be in the circles of the opera-house. Suddenly there is a hush in the conversation, and a genuine burst of applause, as Faraday enters and advances to the middle of the table. He is a man of striking and venerable aspect. His figure is of a spare and active build; his face of an Irish type, kindly and mobile, with powerful grey eyes, which gleam from under the shade of thoughtful brows, half-hidden by a shock of snow-white hair.[1] Perfect master of himself and his subject, respectful of his audience, he begins in a simple and unaffected style, without much preamble, and no flourish of trumpets. From the first he engages the attention of his hearers, and raises their interest by degrees unknown to themselves. His language is lucid and familiar, his movements are easy and collected. But, as he warms to his theme, his rapid thought is winged with an original and fervid eloquence. When he expatiates on the beauty and the mysteries of Nature his enthusiasm reaches the point of ecstasy. His eyes become radiant with light, his hair streams out from his head, and his whole frame seems to quiver with emotion. The rapt audience kindles with the self-same fire, and every face is flushed.[1]

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[1] Faraday believed that his family came from Ireland.

He was particularly happy in his lectures to children. 'With a beaming countenance,' says Dr. Gladstone, 'he begins with something about a candle or a kettle that most boys and girls know, then rises to what they had never thought of before, but which now is as clear as possible to their understandings. And with what delight does he watch the performances of Nature in his experiments! One could fancy that he had never seen the experiments before, and that he was about to clap his hands with boyish glee at the unexpected result! Then with serious face the lecturer makes some incidental remark that goes far beyond natural philosophy, and is a lesson for life.' His pure delight in a good experiment, whether his own or not, was beautiful to see. When Plücker of Bonn showed him the action of a magnet on the luminous discharge in a vacuum tube, he danced about the sheets of light exclaiming, 'Oh! to live in it!'

Some of his apparatus for the juvenile lectures were of the homeliest character. For instance, he made an electrical machine by supporting a glass bottle on an inverted stool. The conductor was a tea-canister lying on a tumbler, and the collector was a toasting-fork.

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[1] See an article by Lady Pollock in *St. Paul's Magazine*, June 1870.

'Lectures,' said Faraday, on one occasion, 'depend entirely for their value upon the manner in which they are given. It is not the matter, it is not the subject, so much as the man; but if he is not competent, and does not feel that there is a need of competency to convey his ideas gently and quietly and simply to the young mind, he simply throws up obstacles, and will be found using words which they will not comprehend.' His own skill was the result of long and patient study.[1]

As an Elder of the Sandemanian body, Faraday often preached at the little meeting-house in Paul's Alley, Red Cross Street, since pulled down. His sermons were plain, fatherly, and scriptural. Opinions seem to be divided on their merits. One who heard him often says they were too parenthetical and rapid of delivery, with little variety or attractiveness; another compares them to a mosaic of texts, puzzling at first, but at length producing an amazing sense of the power and beauty of the whole. A third, who heard him once at Dundee, remarked that 'his face shone like the face of an angel' as he poured out the words of loving exhortation.[2] In general he was reticent about religious matters, but used to marvel that any one should fail to recognise traces of design in Nature. When he thought of how the most destructive elements were balanced in the universe, he was deeply impressed with the power and wisdom of the Creator. Cardinal Wiseman once asked him if he believed the whole Church of Christ was contained in the little sect to which he belonged. 'Oh, no!' replied Faraday; 'but I do believe from the bottom of my soul that Christ is with us.' He considered that the knowledge of a future state could not be attained by any exertion of the mental powers of man, however exalted they might be, but had to be derived from other teaching than his own.

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[1] See his published letters on this head. Dr. Bence Jones, *and Letters of Faraday.*

[2] r. Gladstone's *Life of Faraday.*

Partly by temperament, and partly from a wish to save his time, Faraday took no active interest in politics, art, or literature. Nor did he mingle much in society. His evenings were usually spent at home with his wife and a niece, for he had no children. If the weather was fine, he would walk abroad with them, sometimes as far as the Zoological Gardens, where he would watch the monkeys gambolling, and laugh till the tears ran down his cheeks. Now and then he went to the Opera to hear Jenny Lind, for he was a lover of music, and could sing a good song himself, or to the theatre to see Edmund Kean act, or to some sleight-of-hand entertainment. At home he would join in a game of bagatelle, or read aloud some novel, history, or poem. The stories he liked best had a 'thread in them,' such as *Ivanhoe* or *Monte Cristo*. Macaulay was one of his favourite historians, and Shakespeare his beloved poet; but he was partial to *Childe Harold*, and delighted in the description of a storm on Lake Leman, or in Coleridge's *Hymn to Mont Blanc*.

When a failure of memory warned him to seek a rest, he would go to Brighton or some other seaside place for a change. His niece tells us that on one of these occasions he was delighted because a window of their cottage looked into a blackbird's nest, built in a cherry tree, and that he would go many times in a day to watch the old birds feeding their young.

The rare simplicity and kindliness of his nature was well shown in his love for children. He would soothe their troubles, help in their lessons, and let them play at hide-and-seek in the theatre, or amuse them with tuning-forks and simple experiments. Sometimes his little niece would sit beside him in the laboratory, and in the pauses of his observations he would throw a b[illegible] some water, to amuse her with the [illegible]plosion.

Few scientific men [illegible]ured like Faraday. In 1824 he was elect[illegible]he Royal Society, not without oppositio[illegible]mphry Davy, but after that he never s[illegible] honour. Nevertheless they were rain[illegible]om all parts. He was a member of abou[illegible]he leading learned societies of the world, and possessed in all some ninety-five titles and marks of merit. In 1844 he gained the blue ribbon of science in being appointed one of the eight Foreign Associates of the Academy of Sciences in France. No wonder that Riess, a well-known German electrician, addressed him as 'Professor Michael Faraday, member of all the Academies.' He was awarded all the medals of the Royal Society, and the Copley Medal twice over. He also obtained a Grande Medaille d'Honneur on the occasion of a Paris Exhibition. From the University of Prague he received the degree of Ph.D.; from Oxford D.C.L.; and from Cambridge, LL.D.; while the University of London created him a Senator. He was a Chevalier of the Prussian Order of Merit, a Knight Commander of the Order of St. Maurice and Lazarus, and a Commander of the Legion of Honour. On the resignation of Lord Wrottesley he was offered the presidency of the Royal Society, but he declined it. 'Tyndall,' said he, in speaking of this matter, 'I must remain plain Michael Faraday to the last, and let me now tell you that if I accepted the honour which the Royal Society desires you to confer upon me, I wo not answer for the integrity of my intellect for year.' A knighthood was also proffered hi

Government, but he declined this too. 'I am not one who considers that science can be honoured,' he once remarked. Nevertheless he esteemed his honours, though he neither sought them nor allowed them to move him from his course. He thought they should be given for what a man had done, and not for what he is to do, otherwise talent must be considered a thing to be bought and sold, 'and then down falls that high tone of mind which is the best excitement to a man of power, and will make him do more than a commonplace reward. When a man is rewarded for his deserts, he honours those who grant the reward, and they give it, not as a moving impulse to him, but to all those who by the reward are led to look to that man for an example.' Knighthoods and baronetcies he considered quite unfit for such a purpose. 'Instead of conferring distinction,' he wrote, 'they confound the man, who is one of twenty, or perhaps fifty, with hundreds of others. They depress rather than exalt him, for they tend to lower the especial distinction of mind to the commonplaces of society. An intelligent country ought to recognise the scientific men among its people as a class.' 'Tyndall,' he once said, 'the sweetest reward of my work is the sympathy and goodwill which it has caused to flow in upon me from all quarters of the world.'

When a scientific aspirant inquired of Faraday the cause of his success, he replied, 'The secret is comprised in three words—work, finish, publish.' To this must be added the gift of genius, and a noble character. Faraday was not only a genius, but one of the rarer sort who early recognise their proper line, are fortunate in reaching it, and wise enough to keep true to it. He was a born investigator, who saw around him an increasing multitude of problems. Some one suggested to *him* a certain inquiry. 'There are many things waiting for me,' he answered. He was not a mathematician, and indeed he once boasted that he never made a mathematical calculation in his life, except once when he turned the handle of a Babbage calculating machine.[1] It has been said, however, that he possessed a mathematical mind. This is questionable. In the same sense one might say that he possessed a poetical mind. Yet we believe he never wrote a line of poetry in his life. His mind was probably both mathematical and poetical to some extent, as many minds are. But he tells us himself that he was never able to make a fact his own without seeing it. The descriptions of the best works altogether failed to give him such a knowledge of things as would allow him to form a judgment on them. Thus, when Dr. Tyndall showed him the new phenomenon of calorescence, Faraday watched the piece of cold platinum glow in the focus of the dark rays, but it was only after he repeated the experiment himself that he turned to his friend, and almost hugged him. For the same reason he could never relegate his work to another. It was all done by himself, but his love for experimenting was a veritable passion. Moreover, he was an experimenter in what may be called the grand style, working from a preconceived idea towards an unknown result. Work of this class, which opens up new regions of knowledge, cannot safely be left to a pupil, since the master mind should be there to study the result, and perceive the unexpected hints which Nature sometimes offers. His habitual caution and sagacity of interpretations kept him from making many blunders. 'The thing I am proudest of, Pearsall,' he said to an assistant, 'is that I have never been found to be wrong.' Experience of plagiarism had also taught him never divulge a result until he formally published it.

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[1] Dr. Scoffern in Belgravia, Oct. 1867.

'Faraday,' says M. Dumas, 'is the type of the most fortunate and the most accomplished of the learned men of our age. His hand, in the execution of his conceptions, kept pace with his mind in designing them; he never wanted boldness when he undertook an experiment; never lacked resources to ensure success, and was full of discretion in interpreting results. His hardihood, which never halted when once he had undertaken a task, and his wariness, which felt its way carefully in adopting a received conclusion, will ever serve as models for the experimentalist.' His character was beautiful in all respects. It exhibited that polarity which belongs to a harmonious union of antagonistic elements. His piety was genial and tolerant, while earnest and sincere. He was humble and yet proud, faithful but independent. He was neither an ascetic nor a worldling. To the simplicity of a child he united the experience of a sage; and though his life had been passed in the study of matter which, perhaps, has a tendency to materialise the soul, he was reverent alike to Nature, man, and God. He was very firm, and intolerant of falsehood or injustice, yet his manners were gentle and sympathetic. 'It is better to be blind to the results of partisanship,' he wrote, 'and quick to see good will. One has more happiness in endeavouring to follow the things that make for peace.' 'Underneath his sweetness and gentleness was the heat of a volcano,' writes Dr. Tyndall. 'He was a man of excitable and fiery nature, but through high self-discipline he had converted the fire into a central glow and motive power of life, instead of permitting it to waste itself in useless passion.'[1] In course of time some jealousy had arisen between himself and Davy, but Faraday was ever grateful to his old teacher. 'Wasn't he a great man?'

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[1] *Faraday as a Discoverer.*

he exclaimed to Foucault, while looking at a portrait of Davy which hung in the ante-room of the theatre at Albemarle Street; then turning to the window next the entrance door, he added, 'It was there he spoke to me for the first ti [illegible] hman, with thoughts of Davy's attit [illegible] rely bowed. They descended to the [illegible] Faraday showed him an old note-book wr [illegible] entered the discovery of potassium, with [illegible] capital experiment.' Foucault's reserve w [illegible] l, and he honoured the man who had r [illegible] the greatness and forgot the littleness of [illegible]. Faraday was true to his earliest associations. In his Swiss journal he remarks, 'Clout-nail making goes on here (at Interlaken) rather considerably, and is a very neat and pretty operation to observe. I love a smith's shop, and anything relating to a smithy. My father was a smith.' He once visited the old shop of Mr. Riebau, and also the smithy where his father had worked. At one point he remarked, 'I very nearly lost my life there once. I was playing in the upper room at pitching half-pence into a pint pot close by this hole, and having succeeded at a certain distance, I stepped back to try my fortune further off, forgetting the aperture, and down I fell; and if it had not been that my father was working over an anvil fixed just below, I should have fallen on it, broken my back, and probably killed myself. As it was, my father's back just saved mine.'

'Nature, not education,' says Dr. Tyndall, 'rendered Faraday strong and refined. A favourite experiment of his own was representative of himself. He loved to show that water in crystallising excluded all foreign ingredients, however intimately they might be mixed with it. Out of acids, alkalis, or saline solutions, the crystal came sweet and pure. By some such r process in the formation of his mind, beauty and nobleness coalesced, to the exclusion of everything vulgar and low. He did not learn his gentleness in the world, for he withdrew himself from its culture; and still this land of England contained no truer gentleman than he. Not half his greatness was incorporated in his science, for science could not reveal the bravery and delicacy of his heart.'[1]

In 1858 the Queen offered Faraday a pretty house in the Green at Hampton Court Palace, and there he spent the last years of his busy life. Although he pursued science for its own sake, he had helped in many practical applications, chiefly in connection with the Trinity House and other public bodies. On the 6th of June, 1862, he had the crowning satisfaction to see the electric light of Davy, produced by his own discovery of magneto-electricity, installed at Dungeness, and darting its powerful beam across the Channel.

On the 20th of the same month he delivered a lecture at the Royal Institution on glass-making; but his powers were failing, and he accidentally burnt his notes. At the conclusion he told his audience that he felt he had been before them too long, and bade them a pathetic farewell.

The gentle decline of his powers made the evening of his life a blessing; for the growing weakness of his body was free from pain, and that of his mind did not affect his cheerfulness. 'Barlow, you and I are waiting,' he said to an old friend who was then paralyzed; 'that is what we have to do now, and we must try to do it patiently.' To his niece, Mrs. Deacon, he wrote, 'I cannot think that death has to the Christian anything in it that should make it rare, or other than a constant thought; out of the view of death comes the view of the life beyond the grave, as out of the view of sin (the true and the real view which the Holy Spirit alone can give to a man) comes the glorious hope . . . My worldly faculties are slipping away day by day. Happy is it for all of us that the true good lies not in them. As they ebb, may they leave us as little children trusting in the Father of mercies and accepting His unspeakable gift!' To the Comte de Paris he wrote, 'I bow before Him who is Lord of all, and hope to be kept waiting patiently for His time and mode of releasing me, according to His Divine word, and the great and precious promises whereby His people are made partakers of the Divine nature.' Miss Jane Barnard, his niece, who tended him to the last, has told us that he was surrounded by kind and affectionate friends. He slept a good deal as the paralysis gained upon him; but in his waking hours he would speak quite pleasantly, or repeat the verses of a Psalm. He loved to sit by the western window and watch the fading glories of the sunset. One day his wife drew his attention to a beautiful rainbow spanning the sky, and he said, 'He hath set His testimony in the heavens.' On the 25th of August, 1867, he passed almost imperceptibly away. The funeral, at his desire, was of the simplest order. He was buried in perfect silence, according to the practice of his Church, in the Highgate Cemetery, London.

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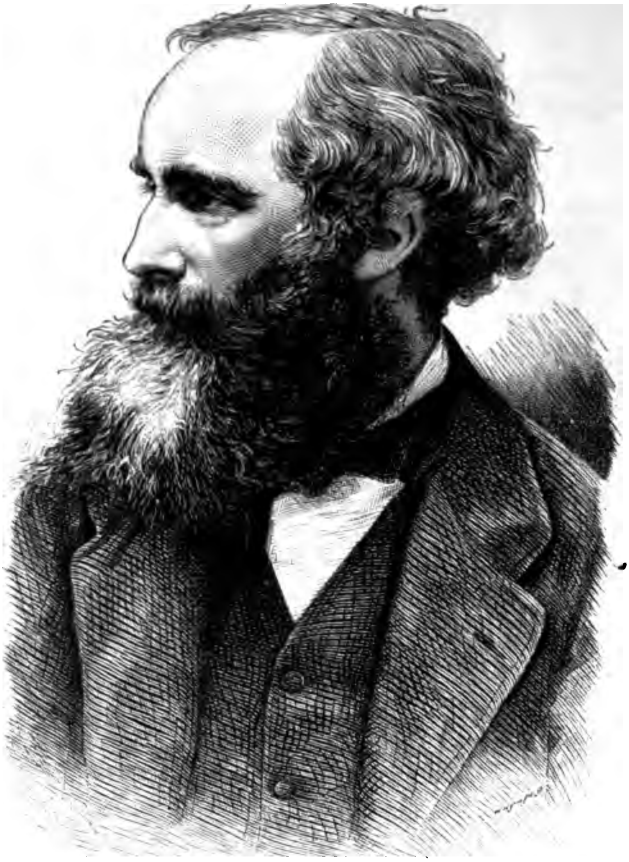
[1] *Faraday as a Discoverer.*



JAMES CLERK MAXWELL.

JAMES CLERK MAXWELL.

Clerk Maxwell, one of the most eminent of mathematical electricians, modestly described himself as th interpreter of Faraday's ideas; but it is being recognised that his fame rests on a wider and more soli foundation.

James Clerk Maxwell, to give his full name, wa born at 14, India Street, Edinburgh, on June 13th 1831. His father, John Clerk, practised for a time a the Scottish bar, and took the name of Maxwell o inheriting the remains of the Middlebie estate i Dumfriesshire from his maternal grandmother, Lad Clerk Maxwell. His mother was Frances Cay, daughter of R. H. Cay, Esq., of North Charlton i Northumberland, and a judge of the Admiralty Cou in Scotland.

John Clerk was a scion of the Clerks of Pennicuik a family of note, which was founded by John Clerk c Kilhuntly in Badenoch, who acquired the barony c Pennicuik about the year 1600, and whose eldest so was created a baronet of Nova Scotia in 1679. Cler Maxwell was, therefore, well descended, and throug his father numbered among his ancestry the Lord Maxwell of border story, as well as Mary Gillies, friend of Marie Stuart, Queen of Scots, and Sir Willia Drummond, the poet of Hawthornden.

His father had a decided taste for the mechanic and industrial arts, and delighted to attend a meetin of the Royal Society in Edinburgh. He was attache to a country life, and soon after the birth of James h removed from Edinburgh and settled on his property. The Middlebie estate, through the imprudence of a former landlord, was now a mere remnant of its older self, and Mr. Maxwell purchased the farm of Glenlair in Kircudbrightshire, on which, about seven miles from Castle Douglas, in a gusset nook between the River Urr and a tributary burn from the west, he built a modest mansion-house of grey stone. He was a good specimen of the country laird, with a fine, strong face, which beamed with a shrewd but kindly eye, a ruddy and hale complexion, and a massive, portly frame—at once the farmer and the gentleman. By disposition he was honest, good-tempered, and considerate. He looked at things from the rational rather than the conventional point of view, and acted with what he called *judiciosity*, doing what seemed wise and prudent. His practical abilities were fully occupied in cultivating his rocky and moorland farms, improving roads or fences, and erecting offices which he himself designed. A reasonable master, he was thoughtful for his dependants, and although, of course, he was 'vexed whiles' he soon recovered his wonted equanimity. Unlike his son, who had not the heart to kill, he was an ardent sportsman and a good shot, but he always tried to spare the victim unnecessary pain. Mrs. Maxwell, like her husband, was practical and matter of fact, but more peremptory in her manner. As an instance of her promptitude and resolution, it is told that when some quarrymen on the estate were injured she attended to them herself, before the arrival of a doctor. She was an excellent housekeeper, and possessed besides some artistic talent, which showed itself chiefly in fancy knitting, but also in playing the organ and in the composition of music.

The childhood of Clerk Maxwell was spent in the solitudes of Glenlair. In after years he told Mr. Lewis Campbell that his first recollection was of 'lying before his father's house, looking at the sun, and *wondering*.' Mrs. Murdoch, his nurse, also relates that when he was about two and a half years old she gave him a new tin plate to play with, and found him holding it to the sun, and sending the reflection round and round the room. He cried to her to bring his papa and mamma, and when they arrived, made the beam glance in their faces. The father was delighted, and on inquiring what he was about, the child replied, 'It is the sun, papa; I've got it in with the plate.' His father told him that when he was a little older he would be shown the moon and stars too. Mrs. Hugh Blackburn, his first cousin, who was then a frequent visitor at Glenlair, tells that his constant query on being shown anything was, 'What's the go o' that?' 'What does it do?' and, again, 'But what's the *particular* go of it?'[1] He was fond of picking up curios and asking inconvenient questions; for example, 'How do you know a whinstone is blue?' He liked to learn the names, the properties, and the reason of things, and he liked still better to make articles for himself with variations of his own device. One of his favourite playthings was a 'magic-disc,' or optical toy of the zoëtrope order. On wet days he would sit and read any book he could get, and sometimes dabbled with his paints and pencil. His memory was good, and his mother, who was his first teacher, inculcated lessons of piety which were never forgotten. At the age of eight he could repeat the whole of the 119th Psalm, and in later life he could give chapter and verse for many passages of Scripture.

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[1] For these and other facts I am indebted to *The Life of James Clerk Maxwell*, by Lewis Campbell and William Garnet, '82.

Such were the faint streaks of his dawning genius, as remembered by his friends. They are so feeble that it may be doubted whether they bespeak his future distinction, or would have been recollected but for that. The childhood of most intelligent boys would furnish similar anecdotes, though the world has never heard of them. Like other boys, he bathed or waded in the burn, and ran about the 'braes,' with his terrier Toby; he ranged the fields with his leaping-pole, or trotted on his pony along the country roads, behind his father's phaeton. For he was active and plucky, as well as observant, and loved to harry the wasps' nests in summer, or venture on the new ice in winter. He was ingenious, too, and discovered that he could paddle himself in a tub about the duck-pond. Blowing soap-bubbles and watching the woodmen felling trees were, of course, juvenile delights.

The freedom and isolation of his childhood was favourable to the development of his idiosyncrasy; but if it fostered his genius, it also encouraged the growth of certain peculiarities of manner which made him something of an oddity. Left so much to himself, he indulged in eccentric and singular conceits, became shy and awkward in company, and contracted a timid hesitancy of speech which never altogether left him.

When he was nine years old he lost his mother; and after being some time under a private tutor, who used him harshly, his father took him to Edinburgh in 1841, and sent him to the Academy.

An only child, brought up in the country under the eyes of his parents, and without much intercourse with other children, he was hardly prepared for the rough reception which he met with from the other boys. They crowded around him during the interval after the first lesson, and proceeded to take his measure. The queer little figure, clad in a homely tunic of hodden grey, with a snouted cap, a dandy frill, and rustic shoes with brass buckles, promised them some sport. 'Who made your shoes?' cried one. But the new-comer was quite a match for them with his wit. He answered in his quaint and quiet way:

'Div ye ken 'twas a man,
And he lived in a hoose,
In whilk was a moose.'

That seems to have been the signal for a general onslaught, and he returned home to his aunt, with whom he lived, minus the skirt of his tunic, and with his pretty frill in tatters.

'Jamsie' was a shy and gentle boy. He was homesick, short-sighted without knowing it, and rather delicate. He seldom joined in the games of his rougher schoolmates, but loved better to go away by himself where he could pore over some old ballad, or draw intricate diagrams, match colours, and construct mechanical models. Hence the boys nick-named him 'Dafty,' and treated him with more or less contempt. But on one occasion he turned furiously on his tormentors, and thereby gained their respect. By-and-by, he found a congenial friend in Lewis Campbell, to whom his affectionate heart opened, and his loosened tongue imparted the rapid flow of his whimsical ideas.

At first he seemed a dull boy, and stood low in his classes, perhaps because he was unready with his answers. But he brightened up afterwards, and excelled in English and Scripture biography. He usually spent his holidays at Glenlair or Pennicuik; and when his father came to Edinburgh they went to visit indus-
al works about the town, or attended some meeting
he Royal Society. But lighter amusements were

not lacking, and sometimes he was taken to the play or circus by his elders, and to hear some popular lecture, such as Catlin's on the North American Indians. One of his letters to his father is ornamented with a flourishing border, and illustrated with a drawing of Catlin in the act of hunting a buffalo. Another contains two cryptograms, to the effect that 'Sea-fyke [the egg-cells of the whelk] is a good thing for polishing with,' and that he was 'copying an old print out of the Delfian [Delphian] Sallust.' In the same letter he mentions that he had been down to Granton, on the Frith of Forth, and 'found out where shellfish breed; they breed in sea-fyke.' He also writes that he has 'cast three seals of lead from the life, or rather from the death: one of a cockle and two mussels, one of which is, or rather will be on this letter.' In another he says: 'I have made a tetrahedron, a dodecahedron, and two more hedrons that I don't know the right names for.' With their conceits of spelling and expression, these letters show the bent his mind was taking. As yet he had not been taught Euclid. Fleeming Jenkin, another of his schoolfellows, tells us that he would stop before a grocer's window to admire the complex curves of the candles, and resolve to understand all about them. The better to recollect his lessons, he drew a plan of the rector's window, and wrote them out in the spaces of the panes; and when he came to recite them in the class he turned his eyes upon the actual window to aid his memory. In 1844 he began the study of geometry, and soon discovered his talent for it. A turn for versifying had showed itself since his twelfth year; and when he was fifteen he not only took the mathematical medal, but the first prize for English verse, with a poem on 'Douglas.'

He began now to exhibit a more distinct originality. In 1846 Mr. D. R. Hay, a decorative painter, published a book on *The First Principles of Symmetrical Beauty*, in which he attempted to reduce all beauty of form and colour to mathematical principles. It was a fascinating subject for Clerk Maxwell, though only in his fifteenth year. He was then studying conic sections, and devised an original mode of drawing a perfect oval. It formed the subject of a paper 'On the Description of Oval Curves, and those having a plurality of foci,' which was communicated to the Royal Society of Edinburgh by Professor James D. Forbes, a friend of his father, and henceforth a dear friend of his own. 'I loved James Forbes,' said Maxwell. Next year the boy identified his method with one already given by Descartes.

He left the Academy this year, 1847, with the first prizes in English and mathematics. He and Peter Guthrie Tait, the future professor of natural philosophy in Edinburgh University, had been accounted the best mathematicians in the school. He very nearly gained the first prize in Latin at the same time. From the Academy he passed to the University, entering the second mathematical class of Professor Kelland, the natural philosophy class of Professor J. D. Forbes, and the logic class of Sir William Rowan Hamilton. At the same time he continued to read Latin and Greek in private; and used to say that making out an author's meaning with no help but the grammar and the dictionary, is one of the best means of training the mind. He subsequently attended the chemical classes of Professor Gregory, and the moral philosophy class of Professor Wilson (Christopher North). Sir William Hamilton seems to have influenced him a great deal, not only his teaching, but his personality; and Professor es formed a high opinion of his abilities. 'His proficiency,' he stated, 'gave evidence of an original and penetrating mind.'

On February 19, 1849, he communicated a paper to the Royal Society of Edinburgh on 'Rolling Curves,' and in the spring of 1850, another on the 'Equilibrium of Elastic Solids.' At this period he was somewhat absent-minded, and a lady of his acquaintance was in the habit of checking this dreaminess at the tea-table with the remark, 'Jamsie, you're in a prop' [proposition].

At Glenlair he had fitted up an old garret as a working 'den' and laboratory, where he could study in quiet, and potter about with his experiments. These were chiefly in optics and chemistry or electricity and magnetism. We find him getting bars for magnets made by the blacksmith, and electro-plating beetles to make scarab seals. He melted away the wax of the mould by means of sunlight and a burning glass. He liked to 'astonish the natives' by showing them some scientific marvel; and was fond of quirks or dodges in his experiments. He sometimes employed the simplest materials, for example a saucer of treacle, to observe the latitude; and a match-box containing glass reflectors to tell the time of day when the sun was hid, by polarising the light from the sky.

On leaving the University it became a question of his future career. His father favoured his own profession, the Bar, but Maxwell had no taste for it; his special talent had already declared itself, and it was decided that he should go to Cambridge. He entered at Peterhouse College in the autumn of 1850, and the next term he removed to Trinity College.

At Cambridge he studied both the classics as well as mathematics and science, but favoured the latter. 'Where *is now Eurip?*' (Euripides) he writes. 'Ay, where? On the top of the lexicon, and behind bunches of observations and calculations. When will he come out? for he was a good soul, after all, and wise (beg his pardon, *wiser*).' Apart from his class-work his general reading was very extensive, and spread over the whole range of literature. 'There is no time for reading a book better than when you need it,' he says; and again, 'I suit my muggery [work] to my temper that day.' But nevertheless he formed plans of regular study, and even tried experiments in sleep and exercise, to find out the most effective system. One of these consisted in running along the corridors and up the stairs of his lodging at two o'clock in the morning; but the other students lay in wait behind their doors, and took flying shots at him with boots and brushes. He went in for walking, boating, swimming, and gymnastics, with occasional fencing and skating. Tait, who had gone to Cambridge before him, relates that he used to jump from a pollard tree, and fall flat on the river, then dive and swim to the other bank, where he mounted another tree and jumped again. He considered this manœuvre good for the circulation. Speaking of the gymnasium to his father, he says, 'By a little exercise of arms every day, one comes to enjoy one's breath, and to sleep better than if one did nothing but walk on level roads.'

Maxwell made many friends at Cambridge, among them Maurice, the divine, and Farrar, now Archdeacon of Westminster. He seems to have lived in a congenial element, and was fond of talking in a discursive vein, at once paradoxical, humorous, and ironical, which was highly diverting. His original observations, curious odds and ends of knowledge, unexpected nalogies, and mystifying propositions were a source less amusement. He became a member of the

Select Essay Club, a sacred band of twelve, irreverently called 'The Apostles,' and supposed to include the finest wits of the University. His essays on 'Decision,' 'Morality,' 'Autobiography,' and other subjects have been preserved, but whatever wisdom they contain is all but inaccessible in a high and rigid style. Here are a few of the simpler passages :—

'The power of making is a man's highest power in connection with Nature.'

'It is a universal condition of the enjoyable that the mind must believe in the existence of a law, and yet have a mystery to move about in.'

'People do not talk of you, or if they do, they make blunders. But they *do* reflect you, and that more faithfully than your looking-glass.'

'Every man has a right, and is bound to become acquainted with himself; but he will find himself out better by intercourse with well-chosen re-agents, than by putting on his own thumbscrews, or by sending round to his friends for their opinion. In the choice of re-agents the first thing to be avoided is incapability and insincerity, which generally go together.'

William Hopkins, the private tutor of Maxwell, considered him one of his most extraordinary pupils, a man of genius with all its eccentricities, and a scientific luminary of the future. 'It is not possible,' said he, 'for that man to think incorrectly on physical subjects.'

In the spring of 1852, Maxwell gained his scholarship ; but he had still two years of hard work before him for the Tripos. In 1853, after the strain of his college examination, he fell ill of a brain fever while on a visit to the Rev. C. B. Taylor, Rector of Otley in Suffolk. This event is said to have confirmed his religious bias, and made him feel that 'Love abideth, though knowledge vanisheth away.'

Maxwell had not confined his efforts solely to his class-work ; the papers he wrote for the Select Essay Club, the *Cambridge Philosophical Magazine*, or the *Cambridge and Dublin Mathematical Journal*, the experiments he made, and the miscellaneous books he read, attest the extraordinary activity of his mind. Little wonder that he overtaxed his strength.

In 1854 he competed for the Wranglership, and the higher ordeal of the Smith's prizes. When he entered the Senate-house to do his first paper, his mind was almost a blank, but, by-and-by, his 'mental vision became preternaturally clear, and on going out again he was dizzy and staggering, and was some time in coming to himself.' When the Tripos was published he was seen to be Second Wrangler, Mr. Routh, of Peterhouse, being senior; but he was bracketed with Routh in the list of Smith prizemen. Any disappointment he may have felt in being second was solaced by more than one distinguished precedent, for example, Sir William Thomson. Maxwell was not a man to apply himself exclusively to 'paying' work, that is to say, the rapid solution of problems likely to swell the number of his marks at an examination; and the Smith prizes are generally regarded as a higher proof of mathematical genius.

He was now a Bachelor-Scholar of the University, and took pupils of his own. Moreover, he was released from the 'grinding' study of his classes, and free to pursue his beloved experiments on optics, magnetism, and electricity. That he was no friend of cramming may be gathered from 'The Student's Evening Hymn,' which he composed in the spring of 1853.

The following aphorism on conduct was written down at this time for his own use, and a copy of it made as a parting gift to his friend Mr. Farrar:—

> 'He that would enjoy life and act with freedom must have the
> ork of the day continually before his eyes. Not yesterday's
> lest he fall into despair, nor to-morrow's, lest he become
> mary—not that which ends with the day, which is a worldly

work, nor yet that only which remains to eternity, for by it he cannot shape his actions.

'Happy is the man who can recognise in the work of to-day a connected portion of the work of life, and an embodiment of the work of eternity. The foundations of his confidence are unchangeable, for he has been made a partaker of Infinity. He strenuously works out his daily enterprises, because the present is given him for a possession.

'Thus ought man to be an impersonation of the divine process of Nature, and to show forth the union of the infinite with the finite, not slighting his temporal existence, remembering that in it only is individual action possible, nor yet shutting out from his view that which is eternal, knowing that Time is a mystery which man cannot endure to contemplate until eternal Truth enlighten it.'

During the summer of 1855 he was reading Poisson, with other works on electricity and fluid motion, and the following winter he wrote a mathematical paper on the lines of force. During the autumn he had gained a Fellowship at Trinity, and was appointed to lecture on optics and hydrostatics. He was also elected a member of the Ray Club, and otherwise led a busy life, helping juniors, nursing sick friends, amongst them his father, whose health began to break, and taking an active share in the scheme of Maurice for the higher education of the working man.

In the spring of 1856, Professor J. D. Forbes informed him that the chair of Natural Philosophy in the Marischal College of Aberdeen was vacant, and having no desire to grow into a Don, he sent in his testimonials.[1] His father wished him to get the post, so that he might spend his vacations at home, but before he was appointed to the chair, the old man died very suddenly on the 2nd of April at Glenlair, where his son was staying at the time. Mr. Maxwell had been a fond and prudent father, and Clerk a dutiful and affectionate son. The following lines express his inmost feelings at the loss he had sustained :—

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[1] 'The transition state from a man into a Don,' he writes, 'must come at last, and it must be painful, like the gradual outrooting of nerves. When it is done there is no more pain, but occasional reminders from some sucker, tap-root, or other remnant of the old nerve, just to show what was there, and what might have been.'

'Yes, I know the forms that meet me are but phantoms o the brain,
For they walk in mortal bodies, and they have not cease from pain,
Oh, those signs of human weakness, left behind foreve now,
Dearer far to me than glories round a fancied seraph' brow.
Oh, the old familiar voices ; ah, the patient waiting eyes
Let me live with them in dreamland while the world i slumber lies,
For by bonds of sacred honour will they guard my so in sleep,
From the spells of aimless fancies that around my sens creep.
They will link the past and present into one continuo life,
While I feel their hope, their patience, nerve me for t daily strife,
For it is not all a fancy that our lives and theirs are on
And we know that all we do is but endless work begun.
Part is left in Nature's keeping, part has entered into re
Part remains to grow and ripen hidden in some livi breast.'

During the same month he received news of l appointment, and after attending to the estate, whi was now his own, he began his lectures at Aberde in November. Besides his regular classes, he al undertook to give some lectures to working m Maxwell found himself at home in college work. not a brilliant expositor, he was a careful and symp thetic teacher, with a real benevolent interest in l pupils. At Aberdeen the professors could draw boo from the college library for the benefit of their frien and Maxwell used the privilege on behalf of t students, who are allowed two volumes at a time. (being checked for the practice, he answered that t students were his friends.

The shadow cast upon his life by the death of his father was deepened by the loss of a college friend in the Indian Mutiny; but the darkest hour precedes the dawn, and a brighter day had begun to break.

'With respect to this "northern hermitage,"' he writes in a letter, 'my cell is pretty commodious. In quitting the coenobitic cloister of Trinity for the howling wilderness of Union Street [Aberdeen], I have not been made an anchoret. It is quite consistent with the eremitic life to modify one's fast in friend's houses four days per week or so. One thing I am thankful for, though perhaps you will not believe it. Up to the present I have not even been tempted to mystify anyone.' He was rather too far north for that. 'Elsewhere,' he remarks, 'Society is pretty steady in this latitude—plenty of diversity, but little of great merit or demerit—honest on the whole, and not vulgar. . . . No jokes of any kind are understood here. I have not made one for two months, and if I feel one coming I shall bite my tongue.'

The house which the young professor liked best to visit was that of Principal Dewar of Marischal College, whose daughter, Katherine Mary, was the centre of attraction. But thoughts of love did not employ all his leisure, for he gained the Adam's prize, offered by St. John's College, Cambridge, with an essay on the 'Rings of Saturn.'

He showed that these peculiar satellites were neither solid nor liquid belts, but streams of meteorites resembling a 'flight of brickbats.' He drew an image from the siege of Sebastopol, and compared them to a state of the atmosphere, such as would arise from the volleys of a park of artillery 30,000 miles long and 100 miles wide, if the balls went spinning round and round in a circle with a radius of 170,000 miles.

He also invented the 'Dynamical top', to illustrate certain problems in dynamics.[1] From childhood a toy called the 'Devil on two sticks' had been an endless source of amusement to him, and his top became the like. He carried it with him to Cambridge, when up for his degree of M.A. during the summer, and exhibited it to a party of old friends in his room one evening. They left it spinning on the table, and early next morning, Maxwell, seeing one of his late guests crossing the quadrangle, jumped out of bed, started the top again, and retired under the blankets. Imagine the astonishment of the visitor to find the top still gyrating!

Maxwell had a predilection for the study of dynamics in real life, whether in the cricket field or the gymnasium. It was said at Cambridge that he used to throw cats out of his window to discover why they always lighted on their feet, and endeavour to prevent it. Perhaps the rumour was a libel; but, at any rate, the mystery seems to have completely baffled him.

In September 1857, Maxwell stayed at Ardhallow, near Dunoon, the residence of Mr. M'Cunn, a son-in-law of Principal Dewar; and the ensuing February his engagement to Miss Dewar was announced. In January, he wrote the following verses, which are among the best of his more serious effusions. They were composed during a walk, while the tune of the 'Lorelei' kept running in his head:—

'Alone on a hillside of heather
  I lay with dark thoughts in my mind,
In the midst of the beautiful weather,
  I was deaf, I was dumb, I was blind.
I knew not the glories around me,
  I thought of the world as it seems,
Till a spirit of melody found me,
  And taught me in visions and dreams.

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[1] See *Transactions* of the Royal Society of Edinburgh, XXI.

For the sound of a chorus of voices
Came gathering up from below,
And I heard how all Nature rejoices,
And moves with a musical flow.
O strange! we are lost in delusion,
Our ways and our doings are wrong,
We are drowning in wilful confusion,
The notes of that wonderful song.

But listen, what harmony holy
Is mingling its notes with our own!
The discord is vanishing slowly,
And melts in that dominant tone.
And they that have heard it can never
Return to confusion again;
Their voices are music for ever,
And join in the mystical strain.

No mortal can utter the beauty
That dwells in the song that they sing;
They move in the pathway of duty,
They follow the steps of their King.
I would barter the world and its glory,
The vision of joy to prolong,
Or to hear and remember the story,
That lies in the heart of that song.'

Early in June Maxwell was married to Miss Dewar. 'James has hitherto lived at the gate of heaven,' said his aunt, Mrs. Wedderburn, on the occasion. He was now within the portals, for wedlock brought no disillusion. He regarded it as a sacrament, a mystical union, typified by that of Christ and His Church. From the first his love had been entwined with his religion, as the following extract from a letter to Miss Dewar will show:—

'6th May, 1858.

'Isaiah li. and Gal. v. I suppose the leaven in verse 9 is the little bit of Judaism that they were going to adopt, on the plea that it is "safer" to do and believe too much than too little; and yet these little things altered the character of the whole of their religion, by making it a thing of labour and wages, instead of an inward growth of faith working by love, which purifies the heart now, and encourages us to wait for the hope of righteousness. But still the desire of the spirit is contrary to the desire of the flesh, the one tending towards God, and the other towards the elements of the world, so that we are kept stretched as it were;

> and this is our training in life. Our flesh is God's making, who made us part of His world; but then He has given us the power of coming nearer to Himself, and so we ought to use the world and our bodies as means towards the knowledge of Him, and stretch always as far as our state will permit towards Him. If we do not, but wilfully seek back again to the elements, as the Israelites did to Egypt, then we are not like infants, or even brutes, but far worse, as recoiling from God and His blessedness. Here are manifest the works of the flesh, which are not only not those of righteousness, but opposed to them; but the fruit of the Spirit comes when, like good trees, we stretch our best affections upwards till we see the sun, and breathe the air, and drink the rain, and receive all free gifts, instead of sending our branches after our roots, down among things that once had life, but now are decaying, and seeking there for nourishment that can only be had from above.
>
> 'See the order of the ripening of the fruit. Now, love brings joy to ourselves, and this, peace with others, and this, long-suffering of their attacks; for why should we be angry? Gentleness is a higher degree of this, being active. Goodness is used in a less general sense than we use it. It seems something like good nature, only better and more manly, and refers to the good disposition of a man among men. Faith is put in here as the *result* of good living, which is true, for it is nourished thereby. Then see what comes of adding faith to a good disposition—meekness, which we cannot afford to have without faith; and lastly, temperance or moderation, which is also founded on faith, and is a virtue that can never be perfect till all the rest are so.'

The colleges of Aberdeen were united in 1860, and the office held by Maxwell was suppressed. He applied for the chair of natural philosophy in Edinburgh, which was resigned by Professor Forbes, but fell to his friend Professor Tait. Soon, however, he obtained a similar post in King's College, London, where his duties were harder than in Aberdeen, and he was obliged to rise in the morning to pursue his original investigations in the garret of his residence at Kensington.

At the Oxford meeting of the British Association
o, he read an important paper on Bernouilli's
of gases, better known as the 'Kinetic' theory,
upposes a gas to consist of myriads of particles

jostling against each other. Maxwell showed that in air at ordinary temperature there are 8,000,000,000 collisions in a second. The subject occupied him to the end of his life, and his contributions to it will be found in the memorial edition of his papers which was published by the Cambridge University Press.

On this occasion he also exhibited his colour box for analysing and combining the different hues of the spectrum. For years past he had been studying the composition of colours, and the nature of colour-blindness. In 1850, when only nineteen, he spoke at a meeting of the British Association, and challenged the theory of Sir David Brewster, which maintained the primary colours to be red, yellow and blue. He invented a colour-top, which, on being spun, blended the colours of tinted paper; and his colour box contained an arrangement of prisms, by which the pure colours of solar light, and not merely the tints of pigments, were mixed in different proportions. With these apparatus he demonstrated that a mixture of blue and yellow does not produce green, but pink, and that the three primary colours are red, green and blue. Vermilion, ultramarine, and emerald are the representatives he chose. By mixing them in proper quantity he produced white light. He devised a pair of spectacles for persons afflicted with colour-blindness. A person who was blind to red was thus able to distinguish between red and green. One glass was red, the other green, so that to the wearer a red object seemed brighter through the red glass, and a green object brighter through the green. He also invented a small instrument for inspecting the living retina. 'Human eyes are very dark and brown as to their retina,' he writes; 'but you can see the image of a candle quite well on it. . . . Dogs' eyes are very beautiful behind; a copper-coloured ground, with glorious bright patches, and networks of blue, yellow, and green, with blood-vessels, great and small.' He also made an improvement in the stereoscope and the zoëtrope, or 'wheel of life.'

For his various researches on light Maxwell was awarded the Rumford Medal of the Royal Society in 1860. The following year, on May 17th, he delivered his first lecture at the Royal Institution, on the theory of the three primary colours. He was a frequent listener to the discourses of Faraday, who was a man after his own heart. On one occasion when Maxwell was caught in the crush of exit from a lecture, Faraday noticed him, and in allusion to his work on molecules, exclaimed, 'Ho, Maxwell, can't you get out? If any one can find his way through a crowd, it should be you.'

In 1862–4 Maxwell was engaged on the sub-committee of the British Association, which was charged with the work of determining the standard ohm. His papers on the subject are published in the collected Reports of 1873. He also undertook a determination of the velocity *v*, which is the ratio of the electromagnetic to the electrostatic unit of electricity, in order to compare it with the known velocity of light.

One of his holidays at Glenlair was marred by a severe attack of small-pox, and another by erysipelas arising from a scratch on the head got while he was riding under the branch of a tree. On these occasions his wife was a devoted nurse; and Maxwell used to say that she had saved his life.

In 1865 he resigned his post at King's College, but continued to deliver his evening lectures to artizans during the winter. In 1866 he retired to his estate, and settled down to literary work; but he also delivered the Bakerian Lecture for the year on the 'Viscosity of Gases.' In 1870 he published his well-known treatise Heat; but his *magnum opus* on *Electricity and*

Magnetism, occupied most of his thoughts, and was fashioned at this period, although not published until 1873.

Faraday, as we have seen, did not believe that the attraction or repulsion produced by electricity and magnetism were caused by an incomprehensible 'action at a distance.' He conceived that they were due to some invisible medium in the space, or 'field,' between electrified and magnetic bodies. It was revealed to him by the iron filings which mustered along the 'lines of magnetic force' in the vicinity of a magnet or a wire conveying an electric current. Maxwell was early fascinated by this new conception, and the chief occupation of his life was to give it a precise mathematical expression. But his penetrating intellect took him far beyond the dreams of Faraday or any other physicist of his time. It led him to identify the medium with the luminiferous ether which permeates the universe, and is the vehicle of light and heat. It forced him to conclude that light and heat themselves are electro-magnetic undulations in this all-pervading element.

His own experiments at King's College tended to confirm his theory. The ratio of the electro-magnetic to the electrostatic unit of electricity, which is known as v, is the velocity of propagation of an electro-magnetic undulation through the supposed medium. If, then, the medium is the luminiferous ether, this velocity will be the same as that of light, which is known to be a wave-motion in the ether. His measurement showed that v is about 179,000 statute miles per second, a figure which is in close agreement with the known velocity of light.[1]

The brilliant experiments of Professor Hertz, of

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[1] Re-determinations of v by Weber and Kohlransch, and others, are in accordance with the theory.

Carlsruhe, carry with them a conviction of its truth. With simple and ingenious devices he has demonstrated that electro-magnetic induction is propagated through the ether in the form of waves, resembling those of light in all but size, and travelling with the same velocity. They can be refracted, polarised, and reflected so as to produce 'interference,' like the waves of light, and, could we increase their rate of oscillation a million-fold, they would, probably, be light. A wire through which these waves were surging would glow with dazzling lustre. But to do so is a task for the future.

It follows from the theory of Maxwell and the results of Hertz, that Faraday's lines of magnetic force are simply lines of stress in the ambient ether. When an electric current is started in a wire, the ether pervading is suddenly disturbed, and a wave flits through it with the speed of light, inducing momentary currents in the conductors which it traverses. When the current in the wire becomes constant the ether assumes a state of rest, but under stress, the lines of which become visible by the trend of iron filings, or the needle of a compass. When the current is stopped the ether relapses into its original state, and there is a return-wave, which induces a reverse current in the conductors through which it passes. Moreover, the action and reaction of the ether gives rise to self-induction in the wire, which is, in fact, the seat or core of an ethereal disturbance.

The discovery is working a revolution in our ideas about electricity. Henceforth the observed phenomena will be regarded in a new light; and fresh experiments will be made from a different point of view.

ght, heat, electricity, and other physical forces were wn to be correlated and interchangeable; but they appear now to be united in one imperial domain by virtue of the universal ether. Much remains to be done. We do not understand that inner mystery which makes the study of electricity so fascinating to inquiring minds. But Maxwell, like another Cortes, has brought us to the elemental ocean, in which the truth may yet be found. The epochising book in which his theory is developed has long been a fountain of inspiration to the mathematical electrician. He has treated the whole subject so exhaustively that when a fresh discovery is announced, we sometimes hear the remark, 'It's all in Maxwell.'

Besides his regular work at Glenlair, his correspondence was so large that he was accommodated with a private letter-box in the wall. The mansion was completed by him according to the original plan of his father. In the afternoon he used to ride about the neighbourhood, and in the evenings he read to his wife from the poets, especially the plays of Shakespeare. On Sunday he went to the kirk, or pondered the writings of some old divine, for he preferred the authors of a bygone age. Family worship was held every day, and some of his prayers were full of meaning. This one was found among his papers:—

> 'Almighty God, who hast created man in Thine own image, and made him a living soul that he might seek after Thee and have dominion over Thy creatures, teach us to study the works of Thy hands that we may subdue the earth to our use, and strengthen our reason for Thy service; and so to receive Thy blessed Word, that we may believe on Him whom Thou hast sent to give us the knowledge of salvation and the remission of our sins. All which we ask in the name of the same Jesus Christ our Lord.'

Maxwell was too reverent to speak of divine things, except to some intimate and sympathetic friend; but he sometimes visited the sick poor of the village of

Kirkpatric-Durham, to read and pray with those who made him welcome.

In the spring of each year he and his wife paid a visit to London; and during the summer of 1867 they visited Italy together. Maxwell then improved his acquaintance with French and German, besides rapidly mastering Italian, with the prime object of conversing with Matteucci. Dutch was the language which he found most difficult to acquire.

In 1870 he received the Keith Medal of the Royal Society of Edinburgh for a paper on 'Reciprocal Figures, Frames, and Diagrams.' He was also elected President of the Mathematical and Physical Section of the British Association at Liverpool; and the University of Edinburgh conferred upon him the degree of LL.D.

For several years Maxwell was examiner in the Mathematical Tripos at Cambridge, and, following Sir W. Thomson, infused fertility into the barren problems which then obtained. He was the leading spirit in the revival of science teaching at Cambridge, which culminated in the establishment of the Natural Science Tripos.

The Cavendish Physical Laboratory was presented to the University by its Chancellor, the Duke of Devonshire; and in this connection a new chair of Experimental Physics was founded. Declined by Sir W. Thomson, it was accepted by Maxwell, but with diffidence, and on the condition that he might retire if he wished at the end of a year.

In October 1871 he delivered his inaugural lecture, and three years later, the new laboratory, which had been designed and equipped under his direction, was opened for experiment. By 1877 it was replete with
tus, some of which were his own gift. He was
and skilful experimenter, and used to whistle

softly to himself while he was at work. His attention was not distracted by talking, and he sometimes addressed his dog. 'Tobi, Tobi,' he would say; then after thinking or working quietly for another while, exclaim: 'It must be so: Plato (*i.e.* Plateau), thou reasonest well.'

In 1873 he delivered a 'Discourse on Molecules' at the Bradford meeting of the British Association, which is one of his happiest efforts at rendering into popular language the abstruse results of physical investigation. His style had become simpler, clearer, and more fluent than of yore, and a certain elegance of diction, a beauty of image, or a tinge of humour, delights the reader, while it conveys the subtlest and profoundest thought. His Rede lecture on the 'Telephone,' delivered at Cambridge in 1878, is another good example of his popular exposition. Maxwell believed that truths which the mathematician arrives at by his proper methods can be lucidly expressed in ordinary language; and these lectures are a proof of it. So is his little book on *Matter and Motion*, which was published by the Society for the Promotion of Christian Knowledge, and may be understood by a child, while it is the puzzle of the mathematician.

In 1876 he was elected a member of Council of the Senate of the University of Cambridge; and filled the office of President of the Cambridge Philosophical Society. At the British Association meeting for that year he presented a report on some experiments which had been made in verifying Ohm's law, by a committee of which he was a member. The University of Oxford also conferred upon him the honorary degree of D.C.L. In 1878 he obtained the Volta Medal, and the degree of Doctor in Physical Science from the University of Pavia.

Maxwell contributed numerous papers to the Royal and other societies, as well as to periodicals. He also wrote for the ninth edition of the *Encyclopædia Britannica.* The article on 'Atoms' is from his pen; and the last he ever wrote is the brief account of Harmonic Analysis. The proof came for revision during his last illness, when he was too weak to read it. For the last seven years of his life he was engaged in editing *An Account of the Electrical Researches of the Honourable Henry Cavendish, F.R.S., between the years* 1771 *and* 1781. This work, which was published in 1879, had occupied much of his time, and Professor Campbell relates that when Maxwell showed him the MS. he inquired, 'What of your own investigations?' 'I have to give up so many things,' said Maxwell; and a look of unwonted sadness came into his eyes. The fragment of a new *Elementary Treatise on Electricity* was found among his papers and published in 1881 by Mr. Garnett, demonstrator in the Cavendish Laboratory.

Maxwell was too reserved to show, still less to prate about, his inner sentiments, but sometimes vented them in stanzas, which he would put into some friendly hand. His gentle nature shrank from controversy, but now and then he would launch a pointed criticism in the playful form of a parody or comic verse. One of his happiest efforts is the travesty on Professor Tyndall's address to the British Association at Belfast, in 1874, which appeared in *Blackwood's Magazine*:—

'In the very beginnings of science, the parsons, who managed things then,
Being handy with hammer and chisel, made gods in the likeness of men;
Till commerce arose, and at length some man of exceptional power
Supplanted both demons and gods by the atoms which last to this hour.

Yet they did not abolish the gods, but they sent them well out of the way,
With the rarest of nectar to drink, and blue fields of nothing to sway.
From nothing comes nothing, they told us, nought happens by chance, but by fate;
There is nothing but atoms and void, all else is mere whims out of date!
Then why should a man curry favour with beings that cannot exist,
To compass some petty promotion in nebulous kingdoms of mist?
But not by the rays of the sun, or the glittering shafts of the day,
Must the fear of the gods be dispelled, but by words and their wonderful play.
So treading a path all untrod, the poet-philosopher sings
Of the seeds of the mighty world, the first beginnings of things;
How freely he scatters his atoms before the beginning of years;
How he clothes them with force as a garment, these small incompressible spheres!
Nor yet does he leave them hard-hearted, he dowers them with love and with hate,
Like spherical small British Asses in infinitesimal state.'

The following parody on Tennyson's *Bugle* was published in *Nature* and signed $\frac{dp}{dt}$, which is the analytical equivalent of the thermo-dynamic formula, J. C. M.:—

'LECTURES TO WOMEN ON PHYSICAL SCIENCE.

PLACE—A small alcove with dark curtains.
The class consists of one member.
SUBJECT—Thomson's Mirror Galvanometer.

The lamp-light falls on blackened walls,
And streams through narrow perforations,
The long beam trails o'er paste-board scales,
With slow-decaying oscillations.
Flow, current, flow, set the quick light-spot flying;
Flow, current, answer, light-spot, flashing, quivering, dying.

O look! how queer! how thin and clear,
And thinner, clearer, sharper growing
The gliding fire! with central wire,
The fine degrees distinctly showing.
Swing, magnet, swing, advancing and receding;
Swing, magnet! Answer, dearest, What's your final reading?

O love! you fail to read the scale
 Correct to tenths of a division,
To mirror heaven those eyes were given,
 And not for methods of precision.
Break, contact, break, set the free light-spot flying;
Break, contact, rest thee, magnet, swinging, creeping, dying.'

Here is another of his best:

'Valentine by a Telegraph Clerk ♂ to a Telegraph Clerk ♀.

The tendrils of my soul are twined
 With thine, though many a mile apart,
And thine in close-coiled circuits wind
 Around the needle of my heart.

Constant as Daniell, strong as Grove,
 Ebullient through its depths like Smee,
My heart pours forth its tide of love,
 And all its circuits close in thee.

O tell me, when along the line
 From my full heart the message flows,
What currents are induced in thine?
 One click from thee will end my woes.

Through many a volt the Weber flew,
 And clicked this answer back to me;
I am thy Farad staunch and true,
 Charged to a volt with love for thee.'

In his later essays for the Erănus (or Pic-Nic) Club at Cambridge, and in numbers of his letters, Maxwell touches on various metaphysical and speculative problems. These fragments are of peculiar interest, owing to his powerful and discriminating intellect, and it is perhaps to be regretted that he did not state his views more fully. He who 'had looked into most philosophical systems,' to use his own words, 'and had seen none that will work without a God,' who had 'read up many queer religions,' but found 'nothing like the old thing, after all,' had, no doubt, something to say which his age would willingly have heard. But Maxwell, while he believed that 'men of ience, as well as other men, need to learn from t,' and thought 'Christians whose minds are scientific are bound to study science, that their view of the glory of God may be as extensive as their being is capable of,' held the opinion that the results which each arrived at in trying to harmonise his science with his Christianity should not be regarded as having any significance except to himself, and that only for a time. He thought that scientific hypothesis changed more rapidly than Biblical interpretation. His profound sense of the immensity of the universe and of our finite intelligence seemed to enlarge for him the domain of reasonable belief. With the eye of mind he had contemplated the inner scene of Nature, and seen the order reigning in that wondrous mechanism, with its ethereal bond uniting the most diverse forms of matter; and it became a favourite thought that, underneath our individuality, there lies a deeper community of being.

In his essay entitled *Psychophysik*, after humorously reviewing different systems, he concludes as follows: 'In this search for information about myself from eminent thinkers of different types, I seem to have learnt one lesson—that all science and philosophy, and every form of human speech, is about objects capable of being perceived by the speaker and the hearer; and that when our thoughts pretend to deal with the subject, it is really only dealing with an object under a false name. The only proposition about the subject, namely, "I am," cannot be used in the same sense by any two of us, and therefore it can never become science at all.'

In one of his letters he writes: 'My notion is that reason, taste, and conscience are the judges of all knowledge, pleasure, and action, and that they are the exponents, not of a code, but of the unwritten law, which they reveal as they judge by it *in presence of the facts.* The facts must be witnessed to by the senses, and cross-examined by the intellect; and not unless everything is properly put on record and proved as fact, will any question of law be resolved at headquarters.'

The last years of his life were saddened by the ill-health of Mrs. Maxwell. He nursed her with rare devotion, and during one illness never slept in bed for three weeks, although he carried on his college work as usual. Entering her bed-chamber one day, the dog sprang up and seized his face, but, fearful of alarming her, he simply caught the animal as it clung and left the room.

In 1877 his own health began to fail. He became dyspeptic, but not deeming the ailment serious, he did not consult a doctor. In 1879, however, there was a marked change in his appearance. His eye had lost its brightness, his gait its elasticity, and he felt a certain difficulty in swallowing. He went to Glenlair in June, hoping to recruit, and taking with him a copy of Clifford's *Lectures* for review. But his brain refused the task, and he knew that he was really ill. His physician put him upon milk diet, and he suffered much from pain and weakness. On October 2, Dr. Sanders of Edinburgh was summoned to Glenlair, and told him he had not a month to live. It was a crucial test of his character and principles; but Maxwell received his doom with all the calm and fortitude of a true Christian. His sole thought seemed to be for his wife. He was afflicted with the fatal disease of which his mother died at the same age. To be nearer medical aid, he returned to Cambridge. Dr. Paget relieved the more painful symptoms, and some hopes were entertained; but he gradually sank. Too weak to think of science, he would lie with closed eyes and muse, occasionally looking up d repeating a verse or proverb. He recited the beginning, 'Look how the floor of heaven,' and dered why Shakespeare had put them in the mouth of a person so frivolous as Lorenzo; another time he said, '"Every good and every perfect gift is from above." Do you know that that is a hexameter? I wonder who composed it.' He often quoted from some favourite hymn; for instance, this of Richard Baxter:

'Lord, it belongs not to my care,
  Whether I die or live,
To love and serve Thee is my care,
  And that Thy grace must give.'

The Saturday before he died, he partook of the Communion at the hands of Dr. Guillemard, his minister, and as the latter was putting on his surplice, repeated the lines on 'Aaron' by George Herbert, beginning:

'Holiness on the head,
  Light and perfections on the breast,
Harmonious bells below, raising the dead,
  To lead them into life and rest;
  Thus are true Aarons drest.
Profaneness in my head,
  Defects and darkness in my breast,
A noise of passion ringing me for dead,
  Unto a place where is no rest;
  Poor priest, thus am I drest.
Only another head
  I have, another heart and breast,
Another music, making live, not dead,
  Without whom I could have no rest,
  In Him I am well drest.'

Dr. Guillemard writes that he received the sacrament with fervid devotion, and spoke of the strength it had given him. '"My dear friend," said Maxwell, "you have been a true under-shepherd to me; read me before you go that beautiful hymn out of the Burial Service, 'Suffer me not at my last hour;'" and his grasp of my hand at parting told me all he felt.'

Maxwell suffered much. The pain was often excruciating; he could hardly lie still a minute, could get no sleep, and lost all appetite for the food he *needed.* Yet he retained his cheerfulness, even his brightness to the last. He never murmured, or showed the least sign of impatience and fretfulness. 'He was never downcast or over-burdened,' writes Dr. Guillemard, 'and yet he was the humblest and most diffident of men, with the deepest sense of his own unworthiness, of his many short-comings, of his neglected opportunities. But he loved, and love had cast out fear. . . . It was a grand sight to see him day by day girding himself calmly and resolutely for the last struggle, and he passed through it undismayed.'

Maxwell had resigned himself to the will of God. A few minutes before he died, when he was being held up in bed, struggling for breath, he said, very slowly and distinctly, 'God help me! God help my wife!' Then, turning to his cousin, Mr. Colin Mackenzie, who was standing by, he said, 'Colin, you are strong; lift me up.' But in a little while he said, 'Lay me down lower, for I am very low myself, and it suits me to lie low.' After this, he breathed deeply and slowly then, with a long look at his wife, he passed away.

His mind, even in the extremity of bodily weakness, remained perfectly clear and unwavering to the end. 'No man,' writes Dr. Paget, 'ever met death more consciously or calmly.'

In these final scenes, the noblest qualities of Maxwell's nature, which habitual reserve had kept some of his acquaintance from discerning, shone forth in all their beauty. 'I had known but little of his inner self before his illness,' writes Dr. Guillemard; 'he was singularly reticent, and though we occasionally discussed a text critically, we rarely got upon doctrine, or anything that touched upon the spiritual life. He was a constant, regular attendant at church, and seldom, if ever, failed to join in our monthly celebration of Holy Communion, and he was a generous contributor to all our parish charitable institutions.

But his illness drew out the whole heart and soul and spirit of the man; his firm and undoubting faith in the Incarnation and all its results; in the full sufficing of the Atonement; in the work of the Holy Spirit.' 'I must say he was one of the best men I have ever met,' says Dr. Lorraine of Castle Douglass; 'and a greater merit than his scientific attainments is his being, so far as human judgment can discover, a most perfect example of a Christian gentleman.'

Maxwell died on November 5th, 1879, and after a memorial service in the chapel of Trinity College, which was attended by the leading men of the university, his body was removed to Glenlair, and buried in the churchyard of Parton.

Maxwell was a black-avised man of middle height, with a well-knit frame, and a springy step. The look of sagacity and good-humour on his bold but handsome features, and his neat, though plain and comfortable dress, bespoke the Scottish laird. But the pallor his cheek contrasting with the jet-black of his hair, a little streaked with grey, the noble brow, so pregnant with thought, and, above all, the deep-set clear brown eye, with its look of intellect, proclaimed the student of no common mark.[1] As he walked along the streets of Cambridge, followed by his dogs, and buried in meditation, from which he would start and turn to call the lagging terriers, one might have set him down for a professor or a man of letters. But during his diviner moods one noticed an ideal lustre in his eye, a sacred light that seemed to be a radiance from heaven.

He possessed a brilliant and many-sided intellect. His imagination delighted in the concrete, and yet was capable of seizing the abstract. He loved definite ideas, but still communed with the infinite. The most diverse tendencies were in him united. His notebooks are filled with solutions of problems, plans of books, and experiments, extracts in prose and verse. His knowledge of English literature was critical and extensive. 'A little literature helps to drive away mathematics from the mind,' he writes. 'I know several men who see all Nature in symbols, and express themselves conformably whether in quintics, or quantics, invariants, or congruents.' Maxwell himself was not entirely free from this habit. In reading the poets, he would criticise the mention of their favourite colours. Rallying a friend who was suffering from depression, he reminds him of what the laird of Dumbiedykes pronounced on a certain occasion. 'It'll be growing when ye're sleeping,' and then remarks, 'What you take for corruption and decay is only stratification.' Or, note his definition, 'A true pleasure is a consciousness of the right action of the faculty or function of power. Happiness is the integral of pleasure, as wisdom is of knowledge.'

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[1] There was a swell or ridge up the middle of his forehead, as though it were 'big' with brain. We have never seen the like on any other person.

Maxwell's character was harmonious as his intellect. The grand simplicity which was its leading trait arose from the perfect equilibrium of complex qualities. There was not the slightest taint of worldliness in his heart. His interest in life and science continued fresh and lively to the end. Those who knew him speak of his 'boyish glee,' his rare influence over dogs, and his love for children. One gentleman remembered seeing him put his favourite black horse Dizzy through its paces, and juggle with his whip, to please the tow-headed bairns of Kilquhanity. His veracity of thought, word, and deed was equally remarkable. In his private room one of the proverbs on the wall was: 'The lip of truth shall be established for ever.' The independence of his character was truly absolute, and free from every trace of conceit or consciousness. His disposition was gentle and unoffending. 'I have been thinking,' he once said, 'how very gently I have been always dealt with. I have never had a violent shove in all my life.' This quietude arose quite as much from his own harmlessness as from his academic career, or his father's prudent care. He never sought fame, nor does he seem to have valued it, though it came. 'The only desire which I can have,' he said, 'is like David, to serve my own generation, by the will of God, and then fall asleep.' When he first went to Cambridge, a lad of twenty, he was recognised as a 'coming man;' but the fact never spoiled him in the least. He remained as simple and sincere as ever. Throughout his life he spoke to all alike, rich or poor, and with an instinctive sense of equality. In politics he was a friend of progress, but a respecter of the established order. In religion, as we have seen, he was a devout Christian, but void of all intolerance or exclusiveness. 'I have no nose for heresy,' he was wont to say. His childlike trust and reverence for sacred things were, we might say, inborn. The reticence he showed with strangers disappeared in more familiar company. His sense of humour was very keen, and he thoroughly enjoyed a good jest or a witty repartee. He seldom laughed outright; only his eyes twinkled expressively. But if his mirth was not explosive, his sadness was never fretful. His temper was marvellously placid and serene, unimperturbed by either anger or impatience. While moderate and genial in his pleasures, he met the various trials of life with a calm and untroubled spirit.

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